

UVQ User Manual

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UVQ development team

UVQ was initially developed to support the assessment of alternative urban water system scenarios within the feasibility stage of the CSIRO Urban Water Program. An existing model, AQUACYCLE, was enhanced by extending the water balance model to include a number of new water flow paths and incorporating contaminant balance modelling. The UVQ development Team is:

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The philosophy behind UVQ

This chapter discusses the philosophy behind UVQ. It describes:

- integrated urban water management
- what UVQ is
- what UVQ does.

Integrated water management

Conventional urban water management considered water supply, wastewater and stormwater as separate entities, planning, delivering and operating these services with little reference to one another. The current urban water systems harvest large volumes of water from remote catchments and groundwater sources and deliver drinking quality water to all urban uses and subsequently collect the generated wastewater. This wastewater is removed, taken to treatment plants usually located on the fringe of the city or town, where the majority is discharged to the surrounding environment. Large volumes of stormwater are also generated within urban areas due to the increased imperviousness of urban catchments. The majority of this stormwater flows out of the urban area, with some management of its quality but little attempt at collection, storage and use. As a result, the adverse impact of conventional urban water management of the water balance of these areas is substantial (Mitchell et al, 1997; 2004).

In comparison, Integrated Urban Water Management takes a comprehensive approach to urban water services, viewing water supply, stormwater and wastewater as components of an integrated physical system and recognises that the physical system sits within an organisational framework and a broader natural landscape.

There are a broad range of tools which are employed within Integrated Urban Water Management, including, but not limited to water conservation and efficiency; water sensitive planning and design, including urban layout and landscaping; utilisation of non-conventional water sources including roof runoff, stormwater, greywater and wastewater; the application of fit-for-purpose principles; stormwater and wastewater source control and pollution prevention; stormwater flow and quality management; the use of mixtures of soft (ecological) and hard (infrastructure) technologies; and non-structural tools such as education, pricing incentives, regulations and restriction regimes.

Integrated Urban Water Management recognises that the whole urban region down to the site scale needs to be considered, as urban water systems are complex and inter-related. Changes to a system will have downstream or upstream impacts that will affect cost, sustainability or opportunities. Therefore, proposed changes to a particular aspect of the urban water system must include a comprehensive view of the other systems and consider the influence on them.

The most important benefit of an integrated approach to urban water systems is the potential to increase the range of opportunities available in order to be able to develop more sustainable systems. In as much as the robustness of ecological systems is increased

through diversity, so too will the sustainability of urban water systems be improved if an increased range of options is made available enabling solutions to be tailored to local circumstances (Speers and Mitchell, 2000).

What UVQ is

UVQ is an urban water balance and contaminant balance analysis tool that was developed to:

- analyse how water and contaminants flow through an urban area,
- examine these flows from source to sink,
- highlight the interconnectedness of the water supply, stormwater and wastewater system and
- provide a tool to investigate how a wide range of non-traditional practices enhance the urban water cycle.

UVQ was initially developed to support the assessment of alternative urban water system scenarios within the feasibility stage of the CSIRO Urban Water Program. An existing model, AQUACYCLE, was enhanced by extending the water balance model to include a number of new water flow paths and incorporating contaminant balance modelling. Thus, UVQ comprises two components – the water flow balance model which calculates water flows through an urban water system; and the contaminant balance model which calculates contaminant loads and concentrations throughout an urban water system.

While there are several models devoted to urban water cycle modelling (see Mitchell et al, 2003), typical representations of the urban water cycle consider the man-made and natural systems as separate entities. Within these two systems, modelling approaches generally only concentrate on one aspect of the water cycle. UVQ integrates all these networks into a single framework to provide a holistic view of the water cycle. UVQ uses simplified algorithms and conceptual routines to provide this holistic and integrated view. Figure 1 illustrates the UVQ framework and the water and contaminant flow paths represented by the model.

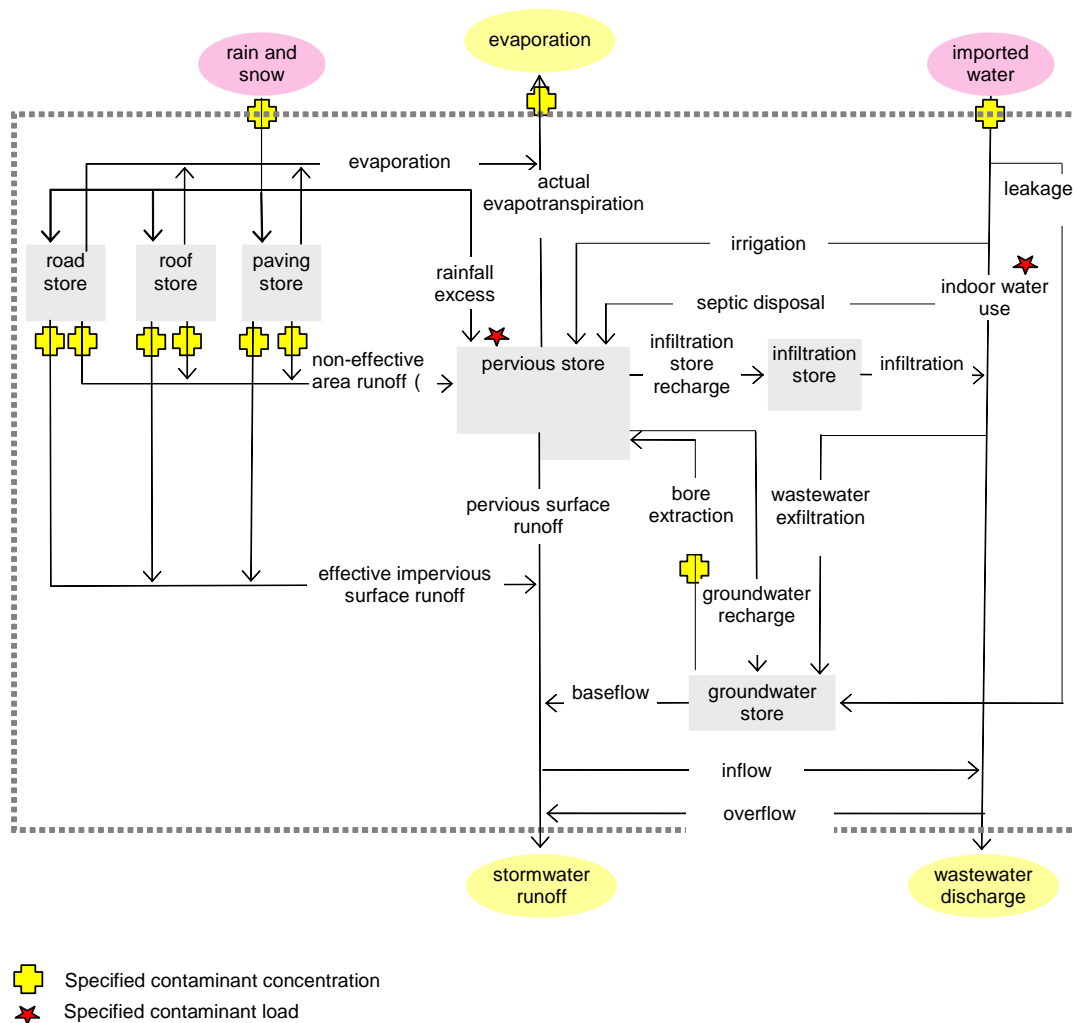


Figure 1: The UVQ framework for conventional systems

The urban water and contaminant balance

The technique of conducting a water balance was initially developed in the 1940's and 1950's by Thornthwaite and Mather (1955) to evaluate the importance of different hydrological parameters under a variety of hydrological conditions (Gleick, 1987). Thornthwaite and Mather (1955) applied the water balance (or budget) to gain information on periods of moisture surplus and deficit, promoting it as a basic tool for evaluation of water resources in rural areas.

In the last forty years the method has evolved into detailed water balance modelling, considering either discrete events or continuous time frames. Due to the variety of disciplines applying the technique to a range of problems, the term 'water balance' has taken on a multitude of meanings (Thornthwaite and Mather, 1957). In regard to UVQ, the urban water balance is defined as 'the comprehensive evaluation of the inputs, outputs and movements of water within an urban volume'.

Since then, the concept of a water balance has been applied to a range of hydrological problems such as stream flow forecasting, prediction of lake and reservoir changes, irrigation demand and the assessment of human impact on the hydrological cycle

(Abdulrazzak et al., 1989). It has proved to be both flexible and readily understandable (van de Ven, 1988; Dexter and Avery, 1991).

Whilst there have been a number of models developed for predicting movement of contaminants within rural areas or from urban areas to sub-surface or open water courses, few have focused on the tracking of water borne contaminants within the existing urban environment in detail. Additionally, none examine the impacts of alternative water servicing options on the flows of contaminants within the urban environment and the effects on discharges to subsurface and open watercourses as well as to existing treatment plants and infrastructure.

Water quality aspects as well as water quantity and sizing of infrastructure are essential assessment considerations for alternative water servicing options. Thus, in addition to providing an integrated approach to water servicing options in the urban environment, UVQ also provides a method for tracking water associated contaminants through the urban environment.

The mapping of the contaminants in the model coincides with the mapping for the water balance. This approach allows direct representation of the effects of alterations to water services on the movement and distribution of contaminants in the urban environment. Contaminants are all modelled conservatively, with no conversion or degradation within the existing infrastructure and with simple mixing and removal processes as the basis for calculations.

What UVQ does

UVQ simulates an integrated urban water system within an urban area and estimates the contaminant loads and the volume of the water flows throughout the water systems from source to discharge point. It has been designed to be very flexible in the manner in which water services are represented and provides the ability to represent a wide range of conventional and more recently emerging techniques for providing water supply, stormwater and wastewater services to either an existing urban area or a site which is to be urbanized.

UVQ uses the concept of an urban volume, which is a cube with unit surface horizontal area that extends from a height above the roof level to a depth below the groundwater table. Figure 2 illustrates the urban volume.

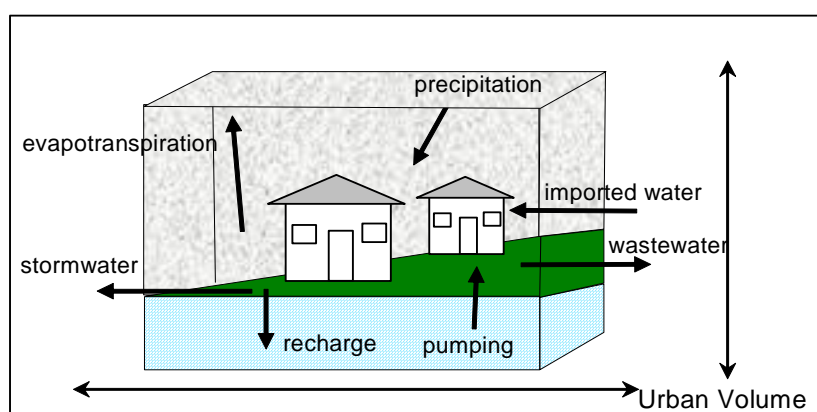


Figure 2 : The conceptual representation of the urban water cycle

This concept allows water transfers to be modelled as depths, with individual surface components accumulating or dispersing water. The concept allows the modelling of a wide range of urban forms and increased model capability.

Some examples of UVQ functions are:

- provide insight into the movement of water and contaminants in the urban area
- ascertain how and where within the urban water cycle contaminants impact on the quality of water
- understand how alterations in different parts of the urban water cycle impact on the rest of the system
- estimate the impacts of different water servicing scenarios on the water cycle of planned urban development
- alter the urban form and degree of drainage connectivity and see how these actions modify the characteristics of stormwater runoff
- identify the quantity of water that may be available for reuse throughout the water cycle and the purposes for which you may reuse it
- investigate the impact of implementing demand and supply side water management actions at different spatial scales such as land block, neighbourhood and whole of study area
- tailor different mixes of servicing approaches to different portions of the study area
- investigate the relationship between the spatial pattern of demand, supply and storage capacity on the reliability of a range of alternative water sources
- provide insight into the potential consequences of implementing a number of non-structural changes to the system such as changing household occupancy, water usage behaviour, use of household chemical products or amount of fertiliser applied to gardens and open spaces

Getting Started

This chapter describes the system requirements and how to get started within UVQ.

System requirements

The operating system requirements for the software are:

Minimum Functionality

- Operating System - Windows 2000 or later. (Windows XP is preferred)
- 1024x768 or higher Screen Resolution Recommended
- Small Fonts Selection for Display Adapter Settings
- Windows Regional Settings set as Australian, UK or US English

Recommended

- Microsoft Excel 2000 or later - English Edition for viewing output files

- Adobe Reader 6.0 - Required for Viewing the User Manual

Getting around UVQ

The UVQ model runs in a Windows™ environment. It uses Windows™ based screens, and navigational devices such as buttons, drop-down menus and toolbars.

UVQ Modelling Approach

The chapter describes UVQ's modelling approach. It outlines the:

- key concepts
- assumptions about the model processes

Key concepts

Before UVQ can simulate an urban water system, you must provide UVQ with a set of simulation parameters that characterize the urban area you want to represent. You must define the characteristics and parameters relating to the:

- Urban Water System
- Contaminant concentrations or loads
- Spatial scales
- Surface areas

Urban water system

UVQ simulates an integrated urban water system defined here to be: “the combined water supply, wastewater and stormwater networks that deliver water to residential, commercial, industrial and other users within an urban area, and manage the wastewater and stormwater generated within that same area”.

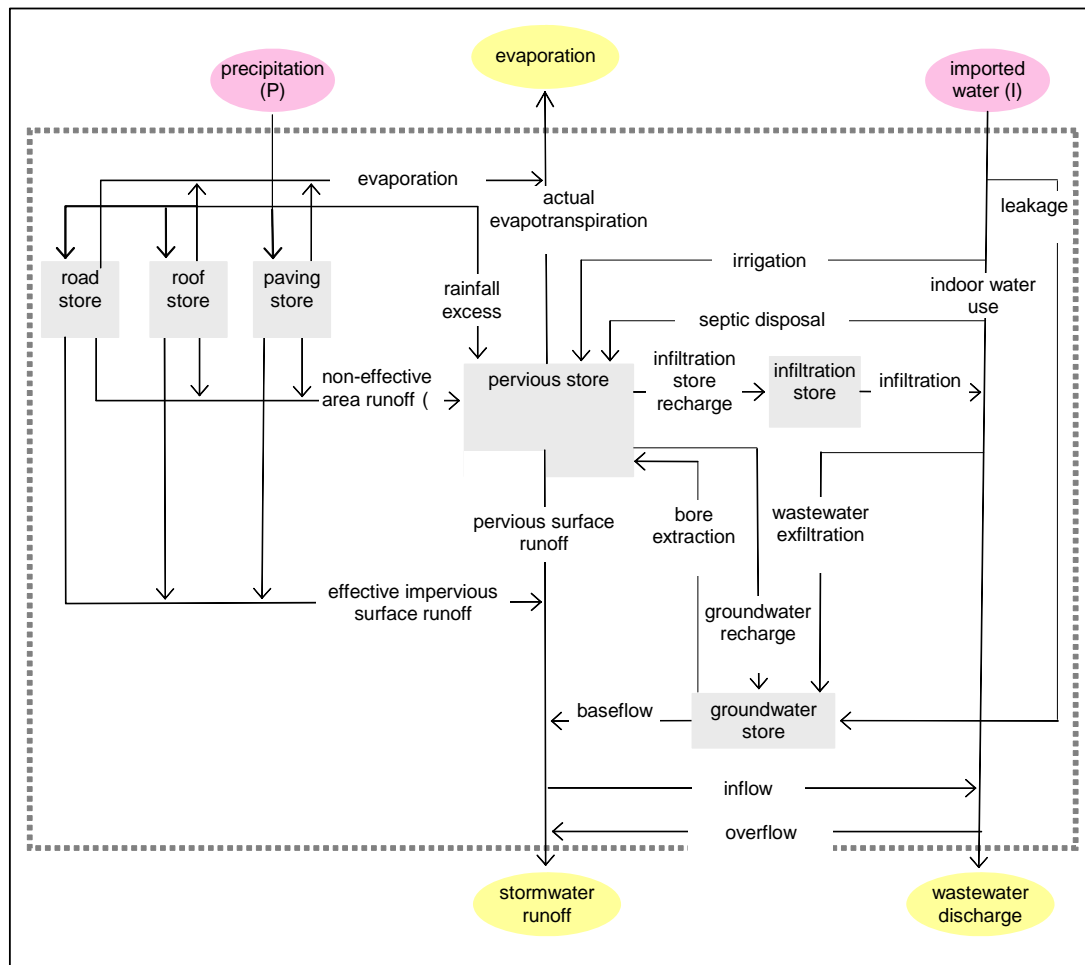


Figure 3 : Integrated conventional urban water system

The UVQ model has been developed with the objective of maximum applicability to all urban areas in both Australia and Europe and so has undergone modification to include representation of a wider range of system configurations. Incorporating this flexibility into the model allows UVQ to represent:

- A variety of land use types; residential, industrial, commercial and open space.
- Different conventional water infrastructure designs such as combined sewers, septic tanks, separate stormwater systems, and groundwater bores
- Local climatic conditions

Another purpose of UVQ is to represent the multitude of alternative options for water supply, stormwater and wastewater service provision, enabling the assessment of the impact of alternative water servicing approaches on the total water cycle. Options that can be represented in UVQ include:

- At land block scale – water usage efficiency, rain tanks, on-site infiltration of roof runoff, greywater collection and sub-surface irrigation, on-site wastewater collection, treatment and reuse
- At neighbourhood scale – open space irrigation efficiency, aquifer storage and recovery, stormwater infiltration, stormwater collection, treatment and use and local wastewater collection, treatment and use

- At study area/development estate scale - stormwater collection, treatment and use and wastewater collection, treatment and use UVQ represents the urban water system at three spatial scales.

The methods described above are provided in Table 1, with a description of some of their sources, uses and limitations.

Table 1 : Methods for available in UVQ for using stormwater and wastewater.

Method	Source(s) of water [#]	Uses [#]	Comments
<i>Spatial scale: Land block</i>			
Rain tank	Roof runoff.	Kitchen, bathroom, laundry, toilet, garden irrigation	Option to include a first flush device and divert to garden, on-site wastewater treatment or stormwater system. Supplies the land block that the rain tank is located within.
Sub-surface irrigation of greywater	One or more of kitchen, bathroom and laundry.	Garden irrigation.	Distributes greywater directly to the garden through a sub-surface drainage field according to the daily irrigation requirement.
On-site wastewater treatment	One or more of kitchen, bathroom, laundry, toilet.	Toilet flushing, garden irrigation.	Treats and stores household wastewater. Supplies the land block that it is located within. Option to dispose of effluent to leachfield, stormwater or wastewater system.
<i>Spatial scale: Neighbourhood</i>			
Stormwater store	One or more of land block runoff, road runoff, public open space runoff, stormwater from upstream neighbourhoods.	Toilet flushing, garden and open space irrigation.	Option to divert a first flush to the stormwater system. A neighbourhood may service particular demands from its own or from another neighbourhood's stormwater store.
Wastewater treatment and storage	One or more of land block wastewater and wastewater from upstream neighbourhoods	Toilet flushing, garden and open space irrigation.	Option to disposing of overflow to stormwater or wastewater system. A neighbourhood may service particular demands from its own or from another neighbourhood's wastewater store.
Aquifer storage and recovery	Neighbourhood stormwater store	Toilet flushing, garden and open space irrigation via the stormwater store	The recharge rate and recovery rate must be specified.
<i>Spatial scale: Study Area</i>			
Stormwater store	Study area stormwater runoff.	Toilet flushing, garden and open space irrigation.	Option to divert a first flush to stormwater system. Any neighbourhood can be supplied by study area stormwater store.

Method	Source(s) of water [#]	Uses [#]	Comments
Wastewater treatment and storage	Study area wastewater discharge.	Toilet flushing, garden and open space irrigation.	Option of disposing of effluent to stormwater or wastewater system. Any neighbourhood can be supplied by study area wastewater store.

[#]where more than one source or use is listed, any or all of the different sources/uses can be selected by the user.

Contaminant concentrations or loads

The mapping of contaminants in the model coincides with the mapping for the water balance, thus directly representing the way in which alterations in the water flows affect the movement and distribution of contaminants. This is a simplification of the processes that occur and does not consider temporal variations in water quality. As UVQ models at a daily time step this approach is applicable and provides detail on sources and flows of contaminants. In addition, as the majority of data collected on temporally varying contaminants flows in the urban environment is expressed as event mean concentrations, this approach is suitable.

During the development of the UVQ software an extensive literature review of reported values for water related contaminant loads and concentrations was undertaken. Table 2 lists the contaminant sources considered in the model. Variability in the load or concentration from each source arises from land use and source characteristics and depending on data availability, certain assumptions can be made. UVQ software developers realized the data hungry nature of the model and that collecting data from case study sites for all the streams required in the contaminant balance is an onerous task. Thus, literature values for many input streams can be used where appropriate and where data for the area being modelled is not available.

The method of describing contaminant loads from sources also allows different systems to be analysed, as flows from various sources can be combined, diverted or treated separately. The assigning of contaminant loads as input to the indoor water use sources also allows the model to effectively deal with water recycled to the house, as the load is independent of the quality of water used.

Table 2: Contaminant profiles required for the contaminant balance.

Contaminant Source	Residential	Commercial	Industrial	Public open space
Water Stream				
Water Supply	✓	✓	✓	✓
Bore Water (Local ground water)	✓	✓	✓	✓
Precipitation	✓	✓	✓	✓
Evaporation	✓	✓	✓	✓
Rainwater tank	✓	✓	✓	
Wastewater Stream				
Greywater	✓	✓	✓	
Kitchen	✓	✓	✓	
Bathroom	✓	✓	✓	
Laundry	✓	✓	✓	
Toilet	✓	✓	✓	
Neighbourhood WWTP effluent	✓	✓	✓	
On-site WWTP effluent	✓	✓	✓	
Stormwater Stream				
Roof	✓	✓	✓	
Roof first flush	✓	✓	✓	
Roads	✓	✓	✓	
Paved areas	✓	✓	✓	
Fertiliser application	✓	✓	✓	✓
Neighbourhood stormwater effluent	✓	✓	✓	✓

Note: Yellow cells in table denote data for contaminant balance calibration rather than model input

Rural open space requires the same data as for public open space.

To track the movement of contaminants through the urban landscape, the water flow volumes calculated by the water balance model are combined with contaminant concentration data.

Temporal scale

UVQ uses a daily time step for computation, with the model output summed to monthly and annual totals.

UVQ uses a climate file to define the temporal period simulated. The maximum time period of a single simulation is limited to 100 years.

Spatial scales

UVQ uses three spatial scales to represent the urban area. The **land block** scale, the **neighbourhood** scale and the **study area** scale. UVQ requires the configuration parameters of each spatial scale before it can simulate the urban area.

Land block

A land block represents a single property that may contain building(s), paved areas, and garden areas. A common example of a land block is a residential property that contains a house, driveway, and garden (Figure 4). For the water balance the user must specify the water usage per occupant for kitchen bathroom, laundry and toilet end uses, the total block area, roof area, paved area and garden area, the occupancy of the household and the percentage of garden area irrigated. For the contaminant balance the user must specify input loads of contaminants to the laundry, kitchen, bathroom and toilet, fertiliser load to the garden and the quality of roof runoff, pavement runoff, drinking water and rainwater.

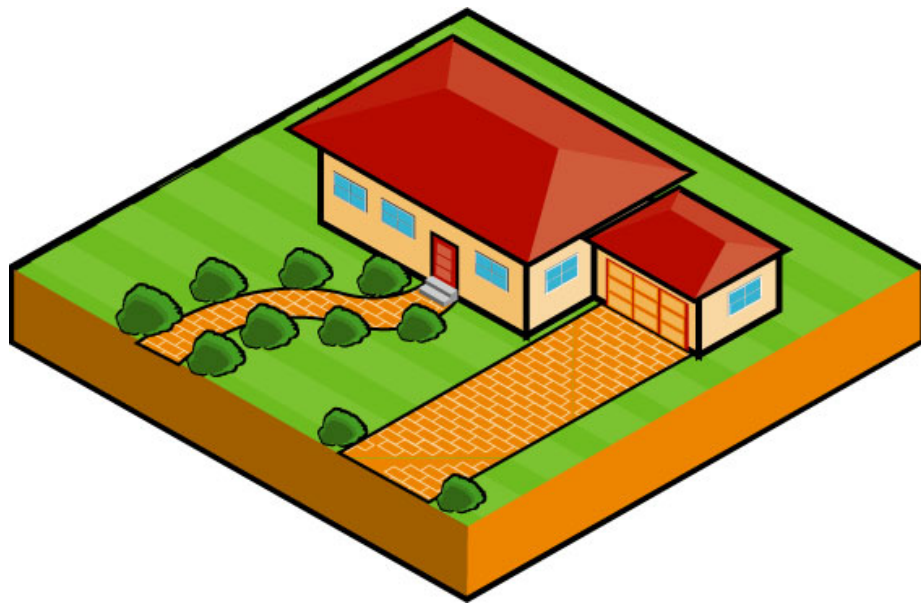


Figure 4 : An example of a residential land block

Land blocks may also represent commercial, industrial or institutional sites such as a factory or a school and the configuration of the land block will change based on how the land block is used. A land block containing an industrial property, for example, may only contain a factory building and car parking areas. Figure 5 illustrates a typical land block used as an industrial site. The user specified values of roof area, paved area and garden area and contaminant loads and concentrations will be significantly different from a residential block.

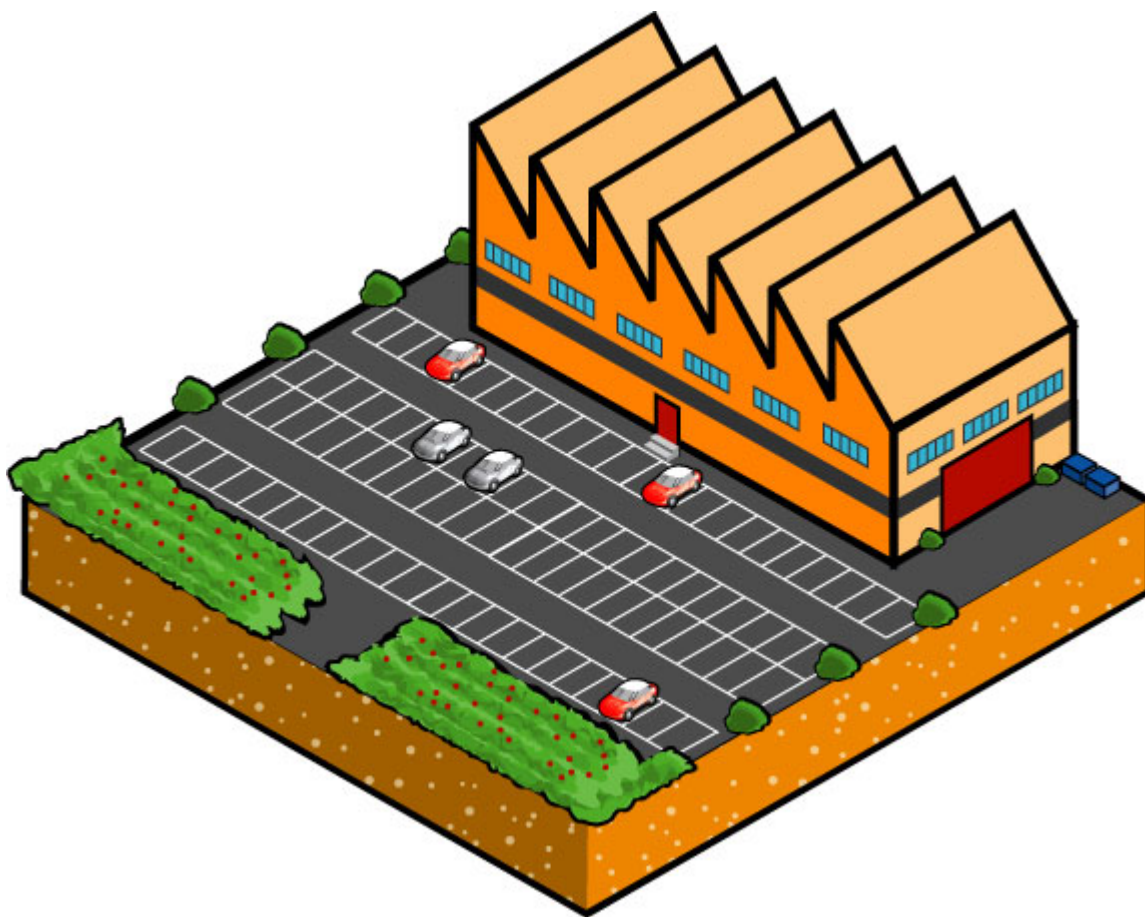


Figure 5 : An example land block used as an industrial site.

Modelling the land block allows you to investigate the effect of the land block characteristics such as size, occupancy, water demands and the cumulative effect of individuals' water usage habits on a neighbourhood or study area.

The land block is the smallest management scale possible for water supply, stormwater runoff, and wastewater disposal which is why it is a useful fundamental spatial scale for this type of modelling.

Neighbourhood

A Neighbourhood represents a multiple number of identical land blocks, in addition to roads and public open space which form a local area or suburb. A common example of a neighbourhood is a group of residential land blocks, with a shared open space and roads (Figure 6). To model the water flows in the neighbourhood, the user must define the number of land blocks in the neighbourhood, the total area, the road and public open space areas, the percentage of open space irrigated and the leakage from potable supply and exfiltration from wastewater collection network. To model the contaminant balance the user must also define contaminant concentration in the runoff from roads and the fertiliser added to open space areas.

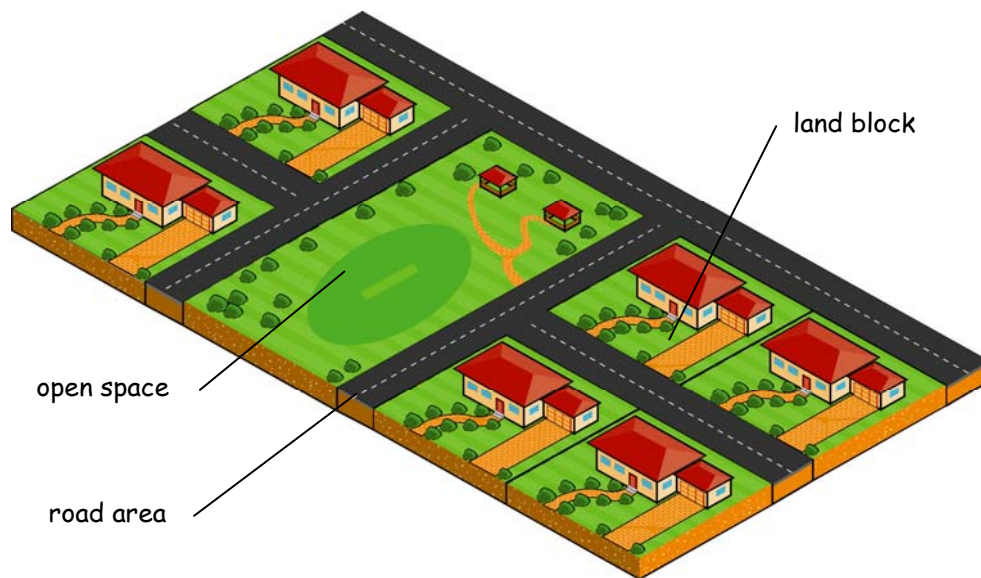


Figure 6 : An example of a residential neighbourhood

Alternatively, the land blocks in the neighbourhood could be used for commercial, industrial or institutional purposes. A neighbourhood that simulates an industrial area may only contain industrial land blocks and roads (Figure 7). A neighbourhood that simulates an area used for institutional purposes such as large university campuses may contain the institutional land blocks, a number of open spaces and roads. Alternatively, a neighbourhood may contain solely open space or solely roads or solely land blocks.

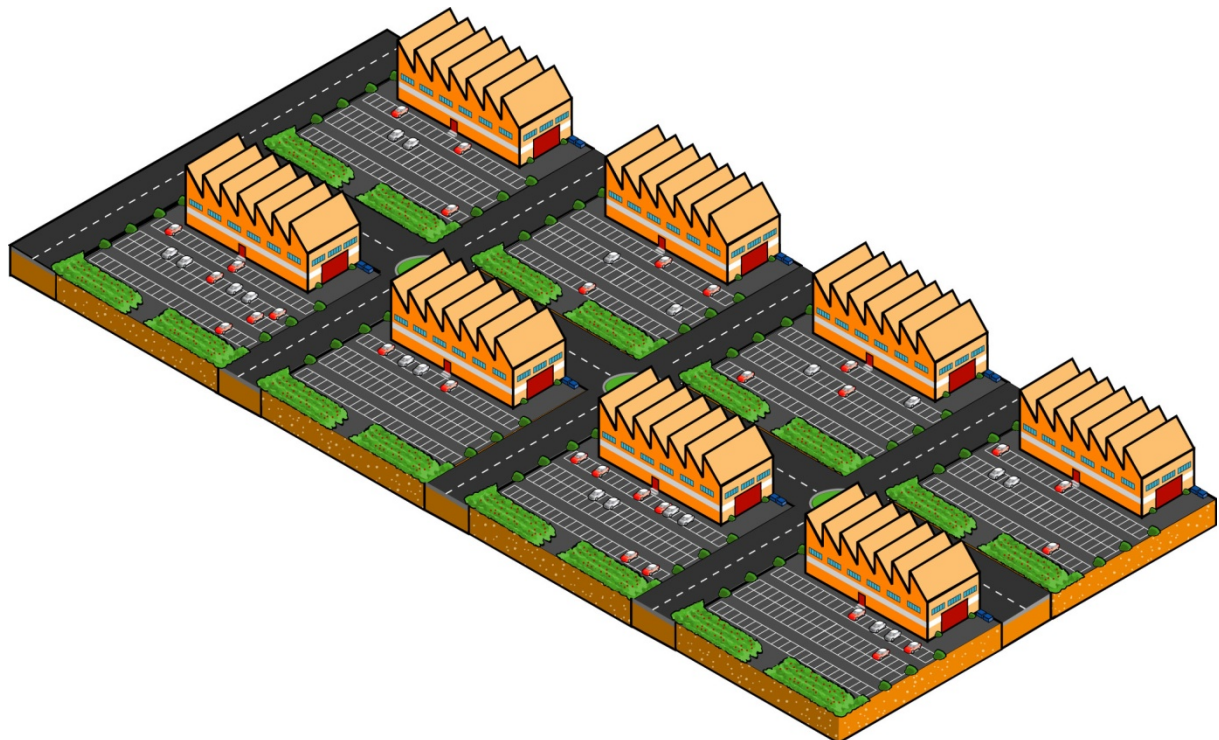


Figure 7 : An example industrial neighbourhood.

Modelling the neighbourhood allows you to investigate the impact of alternate water management options for a neighbourhood and how the demand for water changes according to the pattern of the relevant land use. There is also the opportunity to represent the behaviour of a cooperative group of land blocks which share a stormwater storage facility or wastewater treatment plant.

The land block scale functions still occur when modelling at the neighbourhood and study area scale, but they occur within the land block section of the model. Varying land use and garden watering patterns are accounted for at the land block scale within a neighbourhood.

Study area

A study area represents an urban area containing a number of neighbourhoods that have mixture of land uses such as residential, industrial, commercial and institutional. These neighbourhoods may relate to the suburbs in the study area or areas of single land use. An example of a study area containing residential, commercial and industrial neighbourhoods is shown in Figure 8.



Figure 8 : An example study area.

To model a study area you must identify the number of neighbourhoods that make up the study area and the configuration characteristics of each neighbourhood within the study area.

Modelling a study area allows you to investigate the cumulative effect of different water management strategies within the neighbourhoods within a study area or to explore the feasibility of having different water systems within neighbourhoods that have different characteristics.

The study area is used within the model to represent the spatial scale at which suburban or city water supply and water disposal operations are managed.

The drainage networks linking neighbourhoods, in terms of the flow of stormwater and wastewater can be stated, allowing the spatial relationship between neighbourhoods to be represented and the way in which stormwater and wastewater flow through the study area (Figure 9).

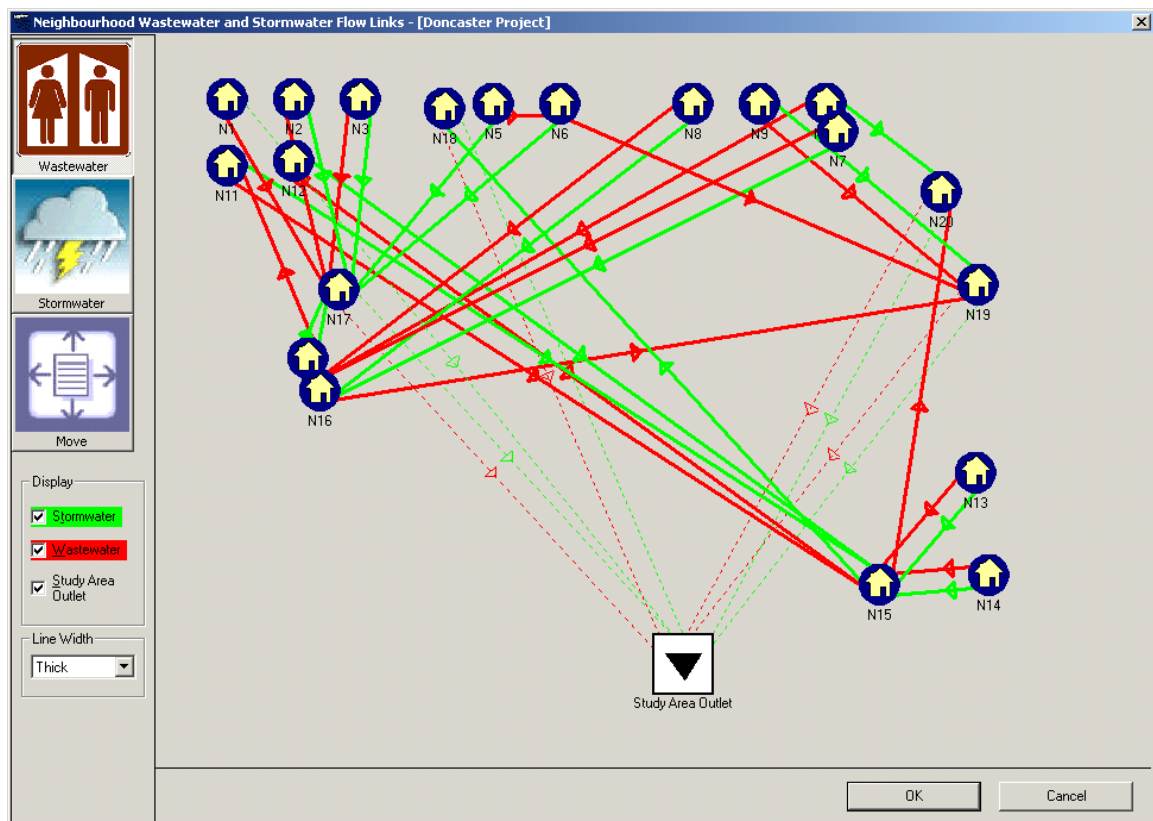


Figure 9 : Example of stormwater and wastewater flows between neighbourhoods as represented in UVQ

Pervious and impervious areas

In the modelling approach used in UVQ two types of surface are represented, pervious and impervious.

Pervious surface areas

Pervious areas are any areas where water penetrates and re-distributes into the soil through infiltration, such as gardens, parks and open spaces. There are two conceptual representations of pervious surface areas and their underlying pervious soil;

1. partial area approach
2. two layer approach

See the UVQ Processes chapter for an explanation of how these two soil store representations differ.

Impervious surface areas

Impervious surface areas are areas where water does not infiltrate through the surface. They are divided into three separate surfaces within each neighbourhood:

- roads,
- roofs and
- paved areas

The redistribution of water from these surfaces requires some understanding of the surface types, their location in the study area and their physical characteristics. The concept of an **effective** paved, road or roof area is used to describe the percentage of impervious area connected directly to the drainage system. The remaining non effective area drains to the pervious surfaces. The concept of **maximum initial loss** is used to estimate the amount of incident water required to wet an impervious surface prior to runoff commencing. These concepts are described further in UVQ Processes and Data descriptions.

Assumptions

A number of assumptions are associated with UVQ and the representation of:

- Snow processes
- Evaporation from surfaces
- Combined sewer systems
- Groundwater store
- Impervious surfaces
- Contaminants from impervious surfaces
- Pervious soil store
- Partial area
- 2 layer soil store
- Irrigation
- Treatment processes
- Surface types in road and open space
- Wastewater exfiltration and overflow processes
- Wetting and drying of pervious and impervious surfaces
- Contaminant flows and loads
- Water supply sources

The assumptions associated with these different processes are described in the following sections.

Snow processes

- Precipitation falls either as all snow or all rain on any given day, depending on the average daily temperature and the user specified snowfall threshold temperature
- There is no variation in snowfall threshold temperature and melt rate factor due to variations in elevation within the study area. The effect of elevation variations is assumed to be minimal
- There is no variation in melt rate factor due to season, snow condition or snow density
- The melt rate factor represents the water depth equivalent amount of snow
- Snow automatically accumulates in garden and open space surfaces. The user can specify whether there is accumulation on paved, roof and road surfaces.
- Rainfall passes straight through the snow pack onto the surface below

Evaporation from surfaces

- The effect of wind turbulence due to increased surface roughness, sheltering by buildings, and other microclimate variations due to urbanisation, does not have a significant impact on the accuracy of the method used to calculate actual evapotranspiration from pervious areas and evaporation from impervious areas. There is little known about the actual difference between urban and non-urban evapotranspiration.
- Actual evapotranspiration of pervious areas varies depending on the soil moisture storage at the beginning of the day, and the evaporative demand estimated by potential evapotranspiration as supplied in the climate input file. This accords with the approach of Boughton (1966) (a simplified Denmead and Shaw (1962) relationship) given in Equation 12.
- The presence of a layer of snow covering a particular surface (garden, public open space, roof, road, paved) does not alter the calculation of actual evapotranspiration from these surface stores
- The maximum rate of evaporation from impervious surfaces is assumed as the potential evapotranspiration as supplied in the climate input file. No allowance is made for the effect of heating of impervious surfaces on the actual evaporation rate. Evaporation is removed from the impervious surface store at the end of the day (effectively after the rain event).
- The concentration of evaporated contaminants is assumed to be the same from all surfaces. Evaporation of all contaminants can be set to zero. Contaminants evaporate from surface stores on all impervious surfaces and from subsurface stores of pervious surfaces.

Combined sewer systems

- Each neighbourhood can have either a separate or combined sewer system
- In a neighbourhood with a combined sewer system, all of the surface runoff generated from impervious surfaces in that neighbourhood (which has not been intercepted and utilised by rainwater tanks or stormwater stores) is directed into the wastewater system.
 - The parameter percentage surface runoff as inflow should be set to 100%.
 - The 'Wastewater System Capacity' should be enabled and set to 0kL.
- Base flow from the groundwater store flows onto the stormwater system, regardless of whether a separate or combined sewer system is selected in a neighbourhood.
- Stormwater flowing into a neighbourhood from an upstream neighbourhood stays in the stormwater system (this can be used to represent streams and creeks flowing through a neighbourhood).
- Overflows from a combined sewer system are directed into the neighbourhood's stormwater system

Groundwater store

- The groundwater store is assumed to be an unconfined aquifer.
- Groundwater recharge spreads uniformly over the entire groundwater store below a neighbourhood; transmissivity is assumed to be infinite. This assumption has little effect on model accuracy unless there is a large amount of water recharging at a fixed point within the modelled area. Any impact on base flow estimation is not significant and does not warrant more sophisticated modelling of the groundwater store.

- There is no deep seepage from the groundwater store. The groundwater store is an infinite source of water and the only discharge from the store is through base flow and/or extraction by a bore.

Impervious surfaces

- All roof, paved and road area is 100% impervious.
- The maximum initial loss from an impervious surface and the effective impervious area are assumed to be constant throughout a rain event and for all seasons during a year.
- The runoff from unconnected impervious areas is assumed to spread evenly across the entire adjacent pervious area (therefore being added to both pervious stores in equal areal depths). Roof and paved area runoff spills onto the pervious area within the same land block. Any road runoff from unconnected areas (non-effective area) spills onto all pervious area within the neighbourhood. In actuality, the runoff would spill onto the edge of the adjacent pervious area and cause an increase in the moisture content of a small area.
- If there is no pervious area adjacent to an impervious area, then the effective impervious area is 100%. All of the impervious surface must be directly connected to the stormwater system since there are no adjacent surfaces for the runoff to spill on to.

Contaminants from impervious surfaces

- Contaminant concentrations in the runoff from the garden and public open space are calculated separately from respective input loads
- Contaminant concentrations in the runoff from the pavement to the garden or stormwater are identical
- No contaminant load is added to stormwater from impervious surfaces but the model calculates the difference between rainfall and stormwater EMCs (event mean concentrations) to provide users with an indicator of this load

Pervious soil store

- All public open space is 100% pervious
- The input and output of water occurs in a set order each day. Precipitation is added to and actual evaporation is removed from the soil moisture stores simultaneously at the beginning of the day. The irrigation demand is calculated and is applied at the end of the day (for more details of the algorithms describing the soil store see UVQ Processes).
- Precipitation and irrigation wet the entire root zone to a constant level. This assumes the moisture is instantaneously distributed throughout the root zone when, in reality, a wetting front forms and the soil is slow to reach a constant soil moisture level throughout.
- Surface ponding and overland flow do not occur until the soil moisture storage capacity of the store is exceeded. This may over-estimate the ability of precipitation and irrigation to wet the soil profile and underestimate runoff in intense rainfall events when infiltration capacity of the soil profile is exceeded.
- There is no lateral movement of moisture in the soil profile. Therefore, there is no transfer of moisture between the soil and groundwater stores in different neighbourhoods.
- All soil below impervious surfaces is regarded as dry.
- If there is no garden on the land block, there can be no leach field associated with a septic tank.

- The removal of contaminants by the pervious soil store is specified by the user as a percentage
- Contaminant concentrations in runoff from the garden and public open space are calculated separately from their different input loads

Partial area approach

Assumptions specific to the partial area approach are:

- There is no transfer of moisture between the two pervious stores.
- Any moisture in excess of either of the two partial area soil storages capacity overflows the store and is separated into surface runoff, groundwater recharge, and infiltration into the wastewater system according to user defined calibration parameters.
- The septic tank system leach field drains into both soil stores. If there is no garden on the land block, there can be no leach field.

2 layer soil store approach

Assumptions specific to the 2 layer soil store approach are:

- Any water entering the upper soil store, in excess of capacity, becomes runoff.
- Irrigation is applied to the upper soil store only.
- Drainage of the soil stores behaves like a simple decay function
- The septic tank system leach field drains into the lower soil store.
- The spoon drain routes water into the lower soil store.
- Infiltration is a constant proportion of the drainage from the lower soil store.

Irrigation

- The model assumes irrigation to be fully effective in recharging the soil moisture stores to the prescribed level with no wastage. In reality part of the water applied to a garden or open space will be wasted as some will evaporate before soaking into the soil, depending on the timing of irrigation and the method used.
- All outdoor water use is due to irrigation of either gardens or public open space.

Treatment processes

- All treatment processes are modelled as continuously stirred tank reactors (CSTRs) and contaminant removal is described as a percentage
- Sludge accumulates in the treatment process
- Treatment process calculations occur on a daily basis and the retained volume and contaminants from the previous day are the starting volume and contaminants for the current day. The retained volume and contaminants reported in results screens are for the final day only

Wastewater exfiltration and overflow processes

- Exfiltration from the wastewater network is a constant proportion of the generated wastewater flow.
- Wastewater overflow is comprised of two components; dry weather overflow and Wastewater System Capacity (formerly labelled wet weather overflow). Dry weather overflow is a constant proportion of generated wastewater flow up to capacity flow levels.

Wastewater System Capacity is all generated wastewater flow in excess of the system capacity.

- Contaminant concentration in exfiltration stream is the same as that in the flow in the wastewater network

Wetting and drying of pervious and impervious surfaces

- Only one wetting and drying cycle occurs within a day. In reality, there may be multiple wetting and drying cycles, due to multiple rain events occurring within the day
- Precipitation is spread evenly over the entire area with no variation due to wind turbulence and localised storms.

Other contaminant balance assumptions

- Specified contaminant loads have no associated water volume

Supply Source preferences

If there is more than one source selected to supply a particular demand (e.g. both rain tank and on-site wastewater treatment unit) then there is a set order in which these sources will be used to meet that demand.

The rules used to determine the priorities for each demand are as follows:

1. Use the lowest quality water source available which meets the requirements of the demand first.
2. Supply indoor water demands before outdoor demands.
3. Use the water sources within the land block before neighbourhood sources.
4. Use neighbourhood scale water sources before study area scale water sources.
5. Use all local sources of water before importing water (reticulated water).

If a particular potential source of water has not been selected by the user, then the next highest priority source is used instead.

Table 3 : Preferences in supplying a demand from multiple available sources

Water Supply source	Water Demand					
	Land block kitchen	Land block bathroom	Land block laundry	Land block toilet	Land block irrigation	Neighbourhood public open space irrigation
Land block direct sub-surface greywater irrigation (kitchen and/or bathroom and/or, laundry)					1	
ater				1	2	
Land block rain tank	1	1	1	2	3	
Neighbourhood wastewater store (located in own Neighbourhood or another Neighbourhood)				3	4	1
Neighbourhood stormwater store (located in own Neighbourhood or another Neighbourhood)				4	5	2
Aquifer storage and recovery (via Neighbourhood stormwater store)				4 ^α	5 ^α	2 ^α
Study area wastewater store				5	6	3
Study area stormwater store				6	7	4
Reticulation	2 ^β	2 ^β	2 ^β	7 ^β	8	5

^α: Aquifer storage and recovery operates in conjunction with a Neighbourhood scale stormwater store (see Aquifer store and recovery operation section),

^β: Reticulated water is automatically supplied to Land block indoor water demands if there is a shortfall in supply from higher priority sources.

Data descriptions

There are eight input screens in UVQ, each requiring specific data about the area to be modelled. The screens have been formatted so that related information is grouped on one screen. The screen descriptions are as follows:

- Project Information screen – details generic information relevant to the whole project area to be modelled
- Physical Characteristics (Physical characteristics of land blocks and neighbourhoods) screen – details pervious and impervious areas in both land blocks and neighbourhood and associated water flows and contaminant loads or concentrations
- Water Flow (Neighbourhood wastewater and stormwater flow links) screen – details the wastewater and stormwater flows between neighbourhoods
- Calibration Variables screen – details the calibration parameters required for the pervious and impervious surfaces and the wastewater system. In addition, this screen can be used to compare simulated stormwater and wastewater flows and concentrations with observed values (part of the calibration process see Tutorial)
- Snow variables (snow accumulation and redistribution) screen – details the temperature thresholds and accumulation and redistribution variables required to simulate the snow processes
- Land Block (land block water management features) screen – details the physical characteristics, supply and usage options and process efficiencies for land block raintank and on-site wastewater treatment systems
- Neighbourhood (neighbourhood water management features) screen - details the physical characteristics, supply and usage options and process efficiencies of neighbourhood stormwater, wastewater and groundwater storage and treatment options
- Study Area (study area water management features) screen - details the physical characteristics, supply and usage options and process efficiencies of study area stormwater and wastewater storage and treatment options.

Project information screen

Figure 10 shows the default **Project Information** screen which describes overall project data. This screen can be used to select the type of soil store to be represented and the contaminants to be simulated (including three user specified options). Further details of the user input to this screen are found in Tutorial.

Project Information - []

Project Description: New Project

Study Area Size: 1 ha

Number of Neighbourhoods: 1

Soil Store Type: ☒ Partial Area ☐ Two Layer

Contaminants

Active	Short name	Long name	Active	Short name	Long name
<input checked="" type="checkbox"/>	Na	Sodium	<input checked="" type="checkbox"/>	Zn	Zinc
<input checked="" type="checkbox"/>	Ca	Calcium	<input checked="" type="checkbox"/>	P	Phosphorus
<input checked="" type="checkbox"/>	Mg	Magnesium	<input checked="" type="checkbox"/>	N	Nitrogen
<input checked="" type="checkbox"/>	Pb	Lead	<input checked="" type="checkbox"/>	TOC	T. O. C.
<input checked="" type="checkbox"/>	As	Arsenic	<input type="checkbox"/>		
<input checked="" type="checkbox"/>	Cd	Cadmium	<input type="checkbox"/>		
<input checked="" type="checkbox"/>	Cu	Copper	<input type="checkbox"/>		
<input checked="" type="checkbox"/>	Ni	Nickel			

OK

Figure 10 : Sample Project Information screen.

Table 1 describes the data requirements for each field within the **Project Information** screen.

Table 1 : Project Information screen data descriptions.

Field	Data Description
Project Description	Brief description of the project. Max. 32 characters. This is usually the name of the area being modelled.
Study Area Size	The total area of the site you are modelling
Number of Neighbourhoods	<p>A study area is divided into zones that have similar surface area dimensions and imported water use requirements. Within UVQ, these zones are represented as neighbourhoods. Maximum number of neighbourhoods is 75.</p> <p>Identify the number of neighbourhoods within your study area and specify the number of here.</p>
Soil Store Type	<p>The two conceptual models of pervious surface soil stores within rainfall runoff models are the partial area runoff approach or the saturation excess approach. UVQ supports both these approaches. It uses the term <i>Partial Area</i> when referring to the partial area runoff approach and <i>2 Layer</i> when referring the saturation excess approach.</p> <p>Choose the approach that best represents your conception of the surface soil store within your study area.</p>
Contaminants for Analysis in this Study Area, Neighbourhoods and Land Blocks	<p>Select the contaminants you wish to represent within your study area.</p> <p>Select the check box and specify the contaminant in the data field. All user specified contaminants are assumed to have concentrations in mg/l</p>

Physical characteristics screen

Figure 11 is a sample of the default **Physical Parameters of land block and Neighbourhood** screen. In this screen the physical characteristics of both the land block and the neighbourhood are described.

In addition, data on the water usage for the four main household indoor uses, toilet, bathroom, laundry and kitchen and the associated contaminant loads is required.

This segregation of end uses allows simulation of different recycled water streams and qualities to the different end uses. This screen also details all the specified contaminant data required to complete the simulation.

Figure 11 : Sample Physical Characteristics of Land Blocks and Neighbourhoods screen.

Table 2 describes the data requirements for the **Physical Parameters of land block and Neighbourhood** screen.

Table 2 : Physical Characteristics of Land Blocks and Neighbourhoods screen data descriptions.

Field	Data Description
Neighbourhood frame	
Total Area (ha)	The neighbourhood spatial scale represents a number of individual properties and any associated roads and public open space. The total area of a neighbourhood is the sum of the open space areas, road areas and the individual properties within the neighbourhood. User input of this value provides a cross check that other areas within the neighbourhood have been specified correctly.
Road Area (ha)	The number of hectares of roads within a neighbourhood Note: the road area is the sum of the roads and the footpaths.

Field	Data Description
Open Space Area (ha)	The number of hectares of open space such as parks, wildlife corridors and so on within a neighbourhood
Percentage of Open Space Irrigated (%)	The percentage of the open space irrigated. The whole area may or may not be irrigated.
Imported Supply Leakage (%)	The percentage of the imported water that leaks into the groundwater through broken and cracked pipes.
Wastewater as Exfiltration (ratio)	The ratio of wastewater exfiltrating (leaking) from the wastewater pipes.
Land Block frame	
Number of Land Blocks	Total number of identical land blocks within this neighbourhood.
Block Area (m ²)	UVQ treats land blocks within a neighbourhood homogeneously. You must specify the average size of the land blocks within your neighbourhood.
Average Occupancy	Average number of people using water indoors within the land block. UVQ accepts whole and decimal numbers.
Garden Area (m ²)	The average garden area within the average land block.
Roof Area (m ²)	The average roof area including sheds and garages within the average land block.
Paved Area (m ²)	The average paved area within the average land block
Percentage of Garden Irrigated (%)	The percentage of the garden area that is irrigated. The whole area may not or may not be irrigated.
Roof Runoff to Spoondrain (ratio)	The ratio of total roof runoff that drains into an on-site soak-away.
Indoor Water Usage & Contaminants frame	
Bathroom, Toilet, Kitchen and Laundry L/c/d	Specify the number of litres of water used per person per day within the bathroom, toilet, kitchen and laundry.
Bathroom, Toilet, Kitchen and Laundry Contaminant Loads mg/c/d	Specify the average contaminant loads due to householders in the bathroom, toilet, kitchen and laundry within a land block.
Other Contaminants frame	
Imported (mg/L)	Specify the contaminant concentration of the water imported into the neighbourhood. This value is used for all imported water to the study area.
Rainfall (mg/L)	Specify the contaminant concentration of the rainfall throughout the neighbourhood. This value is used for all rainfall in the study area.
Pavement Runoff (mg/L)	Specify the average contaminant concentration of the pavement runoff within your average land block.
Roof Runoff (mg/L)	Specify the average contaminant concentration of the average roof runoff within an average land block.
Road Runoff (mg/L)	Specify the event mean contaminant concentrations of the road runoff in a neighbourhood.

Field	Data Description
Roof First Flush (mg/L)	<p>The roof first flush is the water that is prevented from entering a rain water tank to prevent pollutants from entering the tank. The first flush runoff may carry more pollutants in it than the following runoff.</p> <p>Specify the average contaminant concentrations of the roof first flush within an average land block.</p>
Fertiliser to POS (mg /ha/day)	Specify the contaminant loads of fertiliser used on the public open spaces within the neighbourhoods.
Evaporation (mg/L)	<p>Specify the contaminant concentrations of evaporated water from all surfaces within the neighbourhood.</p> <p>Contaminant evaporation from all surfaces is assumed the same.</p>
Groundwater (mg/L)	Specify the contaminant concentration of the groundwater (bore water) leaving the groundwater store within a neighbourhood.
Fertiliser to garden (mg /m ² /day)	Specify the contaminant loads within the fertiliser used on the gardens within land blocks.
Water Outputs frame	
Wastewater from Neighbourhood goes to:	The identification number of the neighbourhood into which the wastewater from this neighbourhood flows. The wastewater flows paths are set up and implemented in the Water Flow screen and so the value in this screen cannot be edited.
Stormwater from Neighbourhood goes to:	The identification number of the neighbourhood into which the stormwater from this neighbourhood flows. The stormwater flows paths are set up and implemented in the Water Flow screen and so the value in this screen cannot be edited.

Water Flows screen

In this screen the stormwater and wastewater flows between neighbourhoods and out of the study area are routed. Figure 12 a) is a simple example of a three neighbourhood case study with all flows of stormwater and wastewater going directly to the study area outlet. Figure 12 b) shows a more complex example of routing of wastewater and stormwater flows between neighbourhoods.

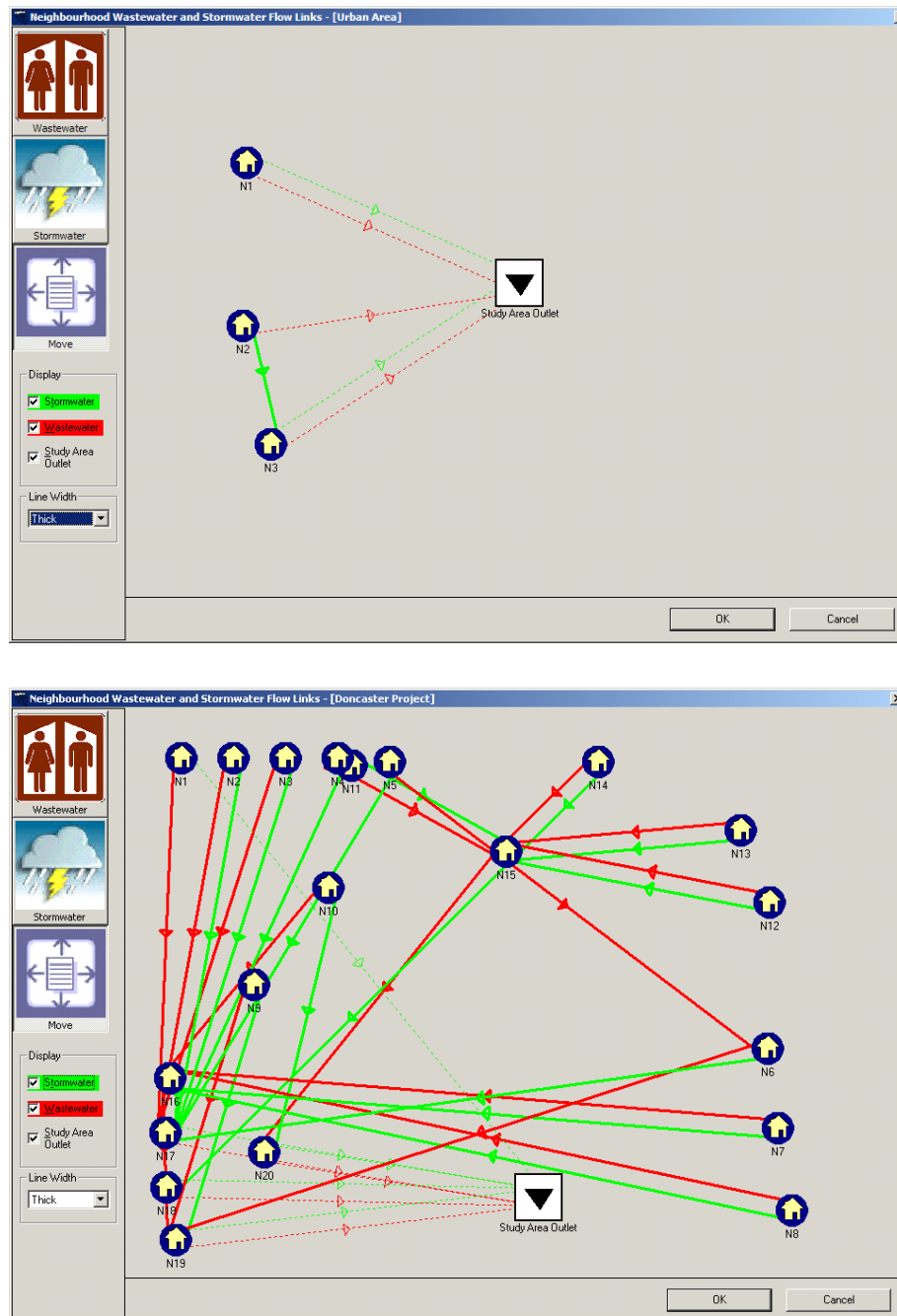


Figure 12 : a) Simple example of Water Flow screen b) Complex example of routing in Water Flow screen

Calibration variables

The calibration variable screen will contain different parameters dependent of the type of soil store selection, partial area or 2 layer. The parameters describing the soil store change dependent upon the modelling approach selected in the Project Description screen

Partial Area screen

Figure 13 a) and b) are the default **Calibration Variables Screens** for both partial area and the 2 layer soil stores. These screens detail the parameters required to calibrate the model to a specific site. The variables defined in this screen are the 'controls' for the output flows and concentrations. The physical characteristics of the area to be modelled (as defined in the **Physical Characteristics** screen) are set values, whereas the calibration variables are used to manipulate the simulated outputs. For this reason this screen also presents the simulated outputs for the neighbourhood and the study area and provides the ability to allow their comparison to observed values.

Calibration Variables - [New Project]

1

Calibration Neighbourhood 1

Stormwater

Percentage Area of Soil Store 1: [Slider] %

Capacity of Soil Store 1: [Slider] mm

Capacity of Soil Store 2: [Slider] mm

Roof Area Maximum Initial Loss: [Slider] mm

Effective Roof Area: [Slider] %

Paved Area Maximum Initial Loss: [Slider] mm

Effective Paved Area: [Slider] %

Road Area Maximum Initial Loss: [Slider] mm

Effective Road Area: [Slider] %

BaseFlow Index Ratio: [Slider] ratio

Base Flow Recession Constant: [Slider] ratio

Contaminant Soil Store Removal %

Set Soil Removal Capacity to 100%

Na [Slider] Pb [Slider] Cu [Slider] P [Slider]

Ca [Slider] As [Slider] Ni [Slider] N [Slider]

Mg [Slider] Cd [Slider] Zn [Slider] TOC [Slider]

Wastewater

Infiltration Index: [Slider] ratio

Infiltration Store Recession: [Slider] ratio

Percentage Surface Runoff as Inflow: [Slider] %

Dry Weather Overflow Rate: [Slider] %

Wastewater System Capacity: ☐ Enabled [Slider] kL

Irrigation

Garden Trigger to Irrigate: [Slider] ratio

Open Space Trigger to Irrigate: [Slider] ratio

this Neighbourhood | Study Area

Average Volumes

Units Scale: ☒ kL/y ☐ ML/y

Observed Simulated

Imported: [Slider] kL/y [Slider] kL/y

Wastewater: [Slider] kL/y [Slider] kL/y

Stormwater: [Slider] kL/y [Slider] kL/y

Quality

☐ Conc. mg/L ☒ Load Kg/y

	Wastewater		Stormwater	
	Observed	Simulated	Observed	Simulated
Sodium				
Calcium				
Magnesium				
Lead				
Arsenic				
Cadmium				
Copper				
Nickel				
Zinc				
Phosphorus				
Nitrogen				
T. O. C.				

Run Template OK Cancel

Figure 13 : a) Calibration Variables Partial area soil store screen b) Calibration variable 2 layer soil store screen

Table 3 describes the data requirements for the **Calibrated Parameters Screen** for both partial area and 2 layer soil store concepts.

Table 3 : Calibration Variables – Partial Area and 2 layer soil store screen data descriptions.

Field	Description
Stormwater frame – partial area (Figure 13 : a) Calibration Variables Partial area soil store screen b) Calibration variable 2 layer soil store screen	
Percentage Area of Soil Store 1 (%)	The proportion of the pervious area (garden and open space) in the neighbourhood which is covered by Soil Store 1.
Capacity of Soil Store 1 (mm)	The maximum depth of water Soil Store 1 can store.
Capacity of Soil Store 2 (mm)	The maximum depth of water Soil Store 2 can store.
Stormwater frame – 2 layer (Figure 13 : a) Calibration Variables Partial area soil store screen b) Calibration variable 2 layer soil store screen	
Maximum Soil Storage Capacity (mm)	The maximum depth of water the upper and lower soil store can hold.
Soil Store Field Capacity (mm)	The level to which the water in the upper and lower soil store freely drains due to the action of gravity.
Maximum Daily Drainage Depth (mm)	The maximum depth of water which will drain from the upper and lower soil store in a day due to the action of gravity.

Field	Description
Roof Area Maximum Initial Loss (mm)	The amount of water it takes to wet the roof surface before runoff occurs.
Effective Roof Area (%)	The proportion of roof area which is directly connected to the roof drainage system.
Paved Area Maximum Initial Loss (mm)	The amount of water it takes to wet the paved surface before runoff occurs.
Effective Paved Area (%)	The proportion of paved area which is directly connected to the land block stormwater system.
Road Area Maximum Initial Loss (mm)	The amount of water it takes to wet the road surface before runoff occurs.
Effective Road Area (%)	The proportion of road area which is directly connected to the neighbourhood stormwater system.
Base Flow Index (ratio) for partial area (Figure 13 : a) Calibration Variables Partial area soil store screen b) Calibration variable 2 layer soil store screen	The ratio of water overflowing from the soil stores due to excess in capacity, which recharges the groundwater.
Drainage Factor (ratio) for 2 layer (Figure 13 : a) Calibration Variables Partial area soil store screen b) Calibration variable 2 layer soil store screen	Controls the rate at which water in the upper soil stores drains into the lower store and the rate at which water in the low store drains to groundwater and the infiltration store.
Base Flow Recession Constant (ratio)	Controls the rate in which water leaves the groundwater store and contributes to the stormwater flowing out of the neighbourhood.
Contaminant Soil Store Removal %	
Highlighted contaminants	The percentage of the contaminant removed from the water as it drains through the soil.
Wastewater	
Infiltration Index (ratio)	The proportion of water overflowing from the soil stores due to excess in capacity which flows into the temporary infiltration store.
Infiltration Store Recession Constant (ratio)	Controls the rate in which water flows into wastewater pipes from the temporary infiltration store.
Percentage Surface Runoff as Inflow (%)	Proportion of surface runoff generated in the neighbourhood which flows into the wastewater pipe system rather than the stormwater system.
Dry Weather Overflow Rate (%)	The proportion of wastewater which overflows from the wastewater system due to pipe chokes.
Wastewater System Capacity (kL)	The trigger represents the maximum amount of wastewater the neighbourhood wastewater system can convey each day. All wastewater flowing into the wastewater system in excess of this capacity then becomes overflow.

Field	Description
Irrigation frame	
Garden Trigger to Irrigate	This is a ratio value between 0 and 1, representing the level of soil wetness that the garden irrigator wishes to maintain. If the soil water storage level in the proportion of the garden that is irrigated drops below this trigger level then irrigation water is requested from the various sources available to it.
Open Space Trigger to Irrigate	This is a ratio value between 0 and 1, representing the level of soil wetness that the open space irrigator wishes to maintain. If the soil water storage level in the proportion of the open space that is irrigated drops below this trigger level then irrigation water is requested from the various sources available to it.
Average Volumes frame - This Neighbourhood tab	
KL/y	Option of displaying observed and simulated imported water, stormwater and wastewater flow results as kL/y or ML/y
Observed Imported	Measured volume of water imported into the neighbourhood. This is a user defined parameter and should be obtained from actual site data if possible. It represents the value that UVQ should replicate when the calibration parameters values are set correctly.
Observed Wastewater	Measured volume of wastewater leaving the neighbourhood. This is a user defined parameter and should be obtained from actual site data if possible. It represents the value that UVQ should replicate when the calibration parameters values are set correctly.
Observed Stormwater	Measured volume of stormwater leaving the neighbourhood. This is a user defined parameter and should be obtained from actual site data if possible. It represents the value that UVQ should replicate when the calibration parameters values are set correctly.
Simulated Imported	UVQ's calculated volume of water imported into the neighbourhood. It provides a guide to how well the calibration parameters defined on this screen are simulating the observed volume of imported water.
Simulated Wastewater	UVQ's calculated volume of wastewater leaving the neighbourhood. It provides a guide to how well the calibration parameters are simulating the observed volume of stormwater.
Simulated Stormwater	UVQ's calculated volume of stormwater leaving the neighbourhood. It provides a guide to how well the calibration parameters are simulating the observed volume of wastewater.
Quality frame - This Neighbourhood tab	
Concentration or Load	Provides the option of using the units of concentration (mg/l) or loads (kg/yr) for observed and simulated imported water, stormwater and wastewater contaminants.

Field	Description
Wastewater Observed Contaminants	Measured event mean concentrations or loads of selected wastewater contaminants leaving the neighbourhood. This is a user defined parameter and should be obtained from actual site data if possible. It represents the value that UVQ should replicate when input and calibration parameter values are set correctly.
Stormwater Observed Contaminants	Measured concentrations or loads of selected wastewater contaminants leaving the neighbourhood. This is a user defined parameter and should be obtained from actual site data if possible. It represents the value that UVQ should replicate when input and calibration parameter values are set correctly.
Simulated Wastewater	UVQ's calculated concentration or load of contaminants leaving the neighbourhood in the wastewater. It provides a guide to how well the set of input parameters are simulating the observed concentrations or loads of stormwater.
Simulated Stormwater	UVQ's calculated concentration or load of contaminants leaving the neighbourhood in the stormwater. It provides a guide to how well the set of input parameters are simulating the observed concentrations or loads of stormwater.

Snow accumulation and redistribution screen

Figure 14 is the default **Snow accumulation and redistribution** screen. This screen is used to select the threshold temperatures for snowfall and snow melt and to define the impervious areas where snow collects and the impervious areas to which snow distributes. Please note, the redistribution process is not available in this version of UVQ. Table 4 describes the data requirements for the **Snow accumulation and redistribution** screen.

Figure 14 : Sample Snow Accumulation and Redistribution screen

Table 4 : Snow accumulation and redistribution screen data descriptions.

Field	Data Description
Simulate Snow Process	Switches on or off the routines in UVQ which simulate snow.
Snowfall threshold (°c)	The threshold daily mean temperature at which precipitation falls as snow rather than rain. The default value is 0 degrees Celsius.
Snow Melt Threshold (°c)	The threshold daily mean temperature at which snow that has built up melts. The default value is 0 degrees Celsius.
Melt Rate Factor (mm/°c/d)	The rate at which snow melts when the temperature is above the Snow Melt Threshold. Typical values range from 2 to 10 mm/d.
Accumulation frame	
Roads in neighbourhood	When this option is selected, snow builds up on the road surfaces in the neighbourhood. If it is not selected then snow falling on the road surface instantaneously melts.
Paved area in land block	When this option is selected, snow builds up on the paved areas within the land blocks of the neighbourhood. If it is not selected then snow falling on the paved surfaces instantaneously melts.
Roofs in land block	When this option is selected, snow builds up on the roof within the land blocks of the neighbourhood. If it is not selected then snow falling on the roofs instantaneously melts.

Field	Data Description
Redistribution frame – not available in this version of UVQ	
Paved Area to garden	If this option is selected, snow that falls on the paved area within a land block is removed to the garden within that land block.
Road to open space	If this option is selected, snow that falls on the roads within the neighbourhood is removed to the user selected open space area, either within that neighbourhood or another neighbourhood.
Road to outside study area	If this option is selected, snow that falls on the roads within the neighbourhood is removed to outside the study area.
Paved area redistribution threshold (mm)	Defines the depth of snow which can accumulate on the paved area before action is taken to remove the snow.
Road area redistribution threshold (mm)	Defines the depth of snow which can accumulate on the road surfaces before action is taken to remove the snow.

Land Block Water Management Features screen

The **Land Block Water Management Feature** screen details treatment processes and water management options available at the land block scale (Figure 15). The physical characteristics and process efficiencies of both raintanks and on-site wastewater units are described on this screen. In addition, direct irrigation with different sources of greywater can be selected as an option.

Figure 15 : Sample Land Block Water Management Features screen

Table 5 describes the data requirements for the **Land Block Water Management Features** screen.

Table 5 : Land Block Water Management Features screen data descriptions.

Field	Description
Raintank frame	
Storage capacity (kL)	The maximum volume of water that an individual rainwater tank within each land block can hold. All of this volume is available for use.
Initial storage level (kL)	The amount of water which is already held in the rainwater tank on the first day of the simulation run.
First flush (kL)	The volume of roof runoff that is diverted away from the rainwater tank at the beginning of a rainfall-runoff event. This is done when the initial roof runoff is of lower quality than the remaining runoff and has the effect of improving the overall quality of water stored in the rainwater tank.
Supplies to: (Bathroom, Laundry, Kitchen, Toilet, Garden)	Water uses that can be selected from the rainwater tank
First flush to: (Stormwater, garden, on site WW)	Provides the option of selection of where the first flush of rainwater is disposed. Standard practice in this regard varies for different countries
Storage backup trigger level (ratio)	When the rainwater tank storage level drops below this level then backup water is requested from the selected neighbourhood stormwater or wastewater store.
Stormwater Store in Neighbourhood No	The neighbourhood stormwater store that is used to provide a backup water source for the rainwater tank.
Wastewater Store in Neighbourhood No	The neighbourhood wastewater store that is used to provide a backup water source for the rainwater tank.
Contaminant Removal Efficiency % frame	
Highlighted contaminants	Specify the removal efficiency that occurs in the raintank for the selected contaminants
Sub Surface Greywater Irrigation frame	
Collected from: (Bathroom, Laundry, Kitchen)	Sources of greywater that are used for sub-surface garden irrigation. One or more can be selected.
On Site Wastewater Unit	
Storage capacity (kL)	The maximum volume of treated wastewater that the onsite treatment unit can hold. All of this volume is available for use.
Exposed surface (m ²)	The surface area of the on-site wastewater treatment unit which is open to the elements rather than covered. On-site wastewater treatment units are typically fully covered.
Initial storage level (kL)	The amount of wastewater which is already held in the on-site wastewater treatment unit store on the

Field	Description
	first day of the simulation run.
Treat the Following Sources (Bathroom, Laundry, Kitchen, Toilet)	The wastewater sources which are directed to the on-site wastewater treatment unit. One or more can be selected.
Supplies to (Toilet, Garden)	Land block water applications which request water from the on-site wastewater treatment unit. Either or both can be selected.
Excess drain to (Stormwater, Sewer, Leach field)	The destination of excess treated wastewater which flows out of the store. Only one can be selected. Selecting the leach field allows the user to represent the behaviour of a septic tank.
Contaminant Removal Efficiency % frame	
Highlighted contaminants	Specify the removal efficiency that occurs in the on-site wastewater unit for the selected contaminants.
Imported Water frame	
Supplies Garden Irrigation	When this option is selected, imported water is used to provide garden irrigation.

Neighbourhood scale management feature screen

There are three tabs in this screen to describe the alternative water management options available at this scale:

- Stormwater & ASR
- Wastewater
- Groundwater

The physical characteristics and process efficiencies of stormwater storage and treatment, wastewater storage and treatment, aquifer storage and recovery and groundwater use are described on this screen.

Stormwater & ASR tab

Figure 16 shows the default **Neighbourhood scale management feature** screen with the **Stormwater & ASR** tab active.

Figure 16 : Sample Neighbourhood Scale Management Features screen with the Stormwater & ASR tab active.

Table 6 describes the data requirements for the **Stormwater & ASR** tab in the **Neighbourhood Scale Management Feature** screen.

Table 6 : Stormwater & ASR tab in the Neighbourhood scale management feature screen data descriptions.

Field	Description
Stormwater store frame	
Storage Capacity (kL)	The maximum volume of water that the stormwater store can hold. All of this volume is available for use.
Exposed Surface (m ²)	The surface area of the stormwater store which is open to the elements rather than covered.
First Flush (kL)	The amount of stormwater which is already held in the store on the first day of the simulation run.
Initial Storage Level (kL)	The volume of stormwater that is diverted away from the stormwater store. This is done when the initial flow of stormwater runoff is of lower quality than the remaining runoff and its diversion improves the overall quality of water in the store.
Act as Infiltration Basin	When this option is selected then the stormwater store acts as an infiltration basin, with the floor of the store being pervious rather than impervious.
Contaminant Removal Efficiency % frame	
Highlighted contaminants	Specify the removal efficiency that occurs in the neighbourhood stormwater store for the selected contaminants.

Field	Description
Sources frame	
Collect Road Runoff	When this option is selected then the road runoff from the neighbourhood is directed into the stormwater store.
Collect Land Block runoff	When this option is selected then the runoff from the land blocks is directed into the stormwater store.
Collect Stormwater from Upstream Neighbourhoods	When this option is selected then the stormwater that flows into this neighbourhood from upstream neighbourhoods is directed into the stormwater store.
Collect Open Space runoff	When this option is selected then the runoff from the neighbourhood open space is directed into the stormwater store.
Stormwater Store Supplies Go To frame	
Garden Irrigation	The water in the stormwater store can be used for garden irrigation in any neighbourhood. Selecting this option enables the Select Neighbourhoods function. Any combination of neighbourhoods can be selected from this drop down list.
Open Space Irrigation	The water in the stormwater store can be used for open space irrigation in any neighbourhood. Selecting this option enables the Select Neighbourhoods function. Any combination of neighbourhoods can be selected from this drop down list.
Toilet	Select this option to use the water in the stormwater store for toilet flushing in any neighbourhood. Selecting this option enables the Select Neighbourhoods function. Any combination of neighbourhoods can be selected from this drop down list.
Aquifer Storage and Recovery frame	
Storage Capacity (kL)	The maximum volume of water that can be held in the underground aquifer store. All of this volume is available for use.
Storage Level (kL)	The amount of water which is already held in the aquifer store on the first day of the simulation run.
Max Recharge Rate (kL/d)	The maximum volume of water that can be pumped into (injected into) the aquifer store each day.
Max Recovery Rate (kL/d)	The maximum volume of water that can be pumped out (recovered from) of the aquifer store each day.

Wastewater tab

Figure 17 is a sample of the **Neighbourhood Water Management Feature** screen with the **Wastewater** tab active.

Neighbourhood 1

Stormwater & ASR | **Wastewater** | Groundwater & Imported Water

Wastewater Store

Storage Capacity: kL

Exposed Surface: m²

Initial Storage Level: kL

☐ Collect Wastewater from Land Blocks in this Neighbourhood
☐ Collect Wastewater from Upstream Neighbourhoods
☐ Overflow to Stormwater (Upstream of neighbourhood stormwater store intake)
☐ Overflow to Wastewater

Contaminant Removal Efficiency %

Na Pb Cu P
 Ca As Ni N
 Mg Cd Zn TOC

Wastewater Store Supplies Go To

Garden
 Open Space
 Toilet

Template OK Cancel

Figure 17 : Sample Neighbourhood Scale Management Features screen with the Wastewater tab active.

Table 7 describes the data requirements for the **Wastewater** tab in the **Neighbourhood Scale Management Feature** screen.

Table 7 : Wastewater tab in the Neighbourhood scale management feature screen data descriptions.

Field	Description
Wastewater store frame	
Storage Capacity (kL)	The maximum volume of water that the wastewater store can hold. All of this volume is available for use.
Exposed Surface (m ²)	The surface area of the wastewater store which is open to the elements rather than covered.
Initial Storage Level (kL)	The amount of wastewater which is already held in the store on the first day of the simulation run.
Collected Wastewater from Land Blocks in this Neighbourhood	When this option is selected then the wastewater leaving the land blocks in the neighbourhood is directed into the wastewater store.
Collect Wastewater from Upstream Neighbourhoods	When this option is selected then the wastewater that flows into this neighbourhood from upstream neighbourhoods is directed into the wastewater store.
Overflow to Stormwater/Wastewater	The user has the choice of directing the overflow from the wastewater store into the neighbourhood stormwater or wastewater system.
Contaminant Removal Efficiency % frame	
Highlighted contaminants	Specify the removal efficiency that occurs in the neighbourhood wastewater store for the selected contaminants.

Field	Description
Wastewater Store Supplies frame	
Garden	The water in the wastewater store can be used for garden irrigation in any neighbourhood. Selecting this option enables the Select Neighbourhoods function. Any combination of neighbourhoods can be selected from this drop down list.
Open Space Irrigation	The water in the wastewater store can be used for open space irrigation in any neighbourhood. Selecting this option enables the Select Neighbourhoods function. Any combination of neighbourhoods can be selected from this drop down list.
Toilet	The water in the wastewater store can be used for toilet flushing in any neighbourhood. Selecting this option enables the Select Neighbourhoods function. Any combination of neighbourhoods can be selected from this drop down list.

Groundwater and Imported Water tab

Figure 18 is a sample of the **Neighbourhood Scale Management Feature** screen with the **Groundwater and Imported Water** tab active.

The screenshot shows a software window titled "Neighbourhood Water Management Features - [New Project]". Inside, there's a tabbed interface with three tabs: "Stormwater & ASR", "Wastewater", and "Groundwater & Imported Water". The "Groundwater & Imported Water" tab is selected. This tab contains two main sections: "Groundwater" and "Imported Water".

In the "Groundwater" section, there is an "Initial Storage Level" input field with a value of "0" and a unit of "kL". Below this, there are two checkboxes under the heading "Supplies": "Garden Irrigation" (unchecked) and "Open Space Irrigation" (unchecked).

In the "Imported Water" section, there is a single checkbox labeled "Supplies Open Space Irrigation" which is checked.

At the bottom of the window, there are three buttons: "Template", "OK", and "Cancel".

Figure 18 : Sample Neighbourhood Scale Management Features screen with the Groundwater and Imported Water tab active.

Table 8 describes the data requirements for the **Groundwater and Imported Water** tab in the **Neighbourhood Scale Management Feature** screen.

Table 8 : Groundwater and Imported Water tab in the Neighbourhood scale management feature screen data descriptions.

Field	Description
Groundwater frame	
Initial Storage Level (kL)	The amount of water which is already held in the groundwater store on the first day of the simulation run.
Supplies (Garden Irrigation, Open Space Irrigation)	Groundwater can be used to provide garden and/or open space irrigation within the neighbourhood.
Imported Water frame	
Supplies Open Space Irrigation	When this option is selected, imported water is used to provide open space irrigation.

Study area parameters

Water servicing options that treat all the stormwater and wastewater from a study site are detailed in the **Study Area Water Management screen** (Figure 19). The physical characteristics and treatment removal efficiencies of wastewater and stormwater storage and treatment are required for this screen. These processes mimic the large scale centralised treatment systems that are found in most developed cities.

Figure 19 : Sample of the Study Area Water Management Features screen.

Table 9 describes the data requirements for the **Study Area Water Management Feature** screen.

Table 9 : Study Area Water Management Feature screen data descriptions.

Field	Data Description
Study Area Wastewater Store frame	
Storage Capacity (kL)	The maximum volume of water that the study area wastewater store can hold. All of this volume is available for use.
Exposed Surface (m ²)	The surface area of the study area wastewater store which is open to the elements rather than covered.
Initial Storage Level (kL)	The amount of wastewater which is already held in the store on the first day of the simulation run.
Overflow Stormwater/Wastewater	The user has the choice of directing the overflow from the study area wastewater store into the neighbourhood's stormwater system or wastewater system.
Supplies Select Neighbourhoods frame	
Garden Irrigation	The water in the wastewater store can be used for garden irrigation in any neighbourhood. Selecting this option enables the Select Neighbourhoods function. Any combination of neighbourhoods can be selected from this drop down list.
Open Space Irrigation	The water in the wastewater store can be used for open space irrigation in any neighbourhood. Selecting this option enables the Select Neighbourhoods function. Any combination of neighbourhoods can be selected from this drop down list.
Toilet	The water in the wastewater store can be used for toilet flushing in any neighbourhood. Selecting this option enables the Select Neighbourhoods function. Any combination of neighbourhoods can be selected from this drop down list.
Contaminant Removal Efficiency % frame	
Highlighted Contaminants	Specify the removal efficiency that occurs in the study area wastewater store for the selected contaminants.
Study Area Stormwater Store frame	
Storage Capacity (kL)	The maximum volume of water that the study area stormwater store can hold. All of this volume is available for use.
Exposed Surface (m ²)	The surface area of the study area stormwater store which is open to the elements rather than covered.
First Flush (kL)	The volume of stormwater that is diverted away from the study area stormwater store. This is done when the initial flow of stormwater runoff is of lower quality than the remaining runoff and has the effect of improving the overall quality of water in the store.
Initial Storage Level (kL)	The amount of stormwater which is already held in the store on the first day of the simulation run.

Field	Data Description
Supplies Select Neighbourhoods frame	
Garden Irrigation	The water in the stormwater store can be used for garden irrigation in any neighbourhood. Selecting this option enables the Select Neighbourhoods function. Any combination of neighbourhoods can be selected from this drop down list.
Open Space Irrigation	The water in the stormwater store can be used for open space irrigation in any neighbourhood. Selecting this option enables the Select Neighbourhoods function. Any combination of neighbourhoods can be selected from this drop down list.
Toilet	The water in the stormwater store can be used for toilet flushing in any neighbourhood. Selecting this option enables the Select Neighbourhoods function. Any combination of neighbourhoods can be selected from this drop down list.
Contaminant Removal Efficiency % frame	
Highlighted Contaminants	Specify the removal efficiency that occurs in the study area stormwater store for the selected contaminants

UVQ Processes

The chapter describes in detail the processes represented within UVQ and the algorithms used for their calculation. The process are described in three sections, firstly the generic concepts of both the water and contaminant balance are described. These concepts are applicable to all other processing steps occurring in UVQ.

Secondly, the standard and alternative water system processes are explained. These are the processes which describe the hydrologic water cycle such as precipitation, pervious and impervious surface runoff, evaporation, soil store processes and groundwater recharge. Also described are the anthropogenic water cycle processes; irrigation, groundwater extraction, imported water supply and leakage, stormwater discharge, wastewater discharge, infiltration, exfiltration and overflow. The alternative water management approaches that are represented in UVQ include; rainwater tanks, greywater irrigation, on-site wastewater systems, neighbourhood and study area stormwater and wastewater stores and treatment processes, aquifer storage and recovery (ASR), the transfer of water between neighbourhoods

The final section describes the contaminant balance operations associated with both standard and alternative processes. The section describes the basic operations generic to all contaminant balance operations, contaminant balance operations between spatial scales and specific calculations for individual water system components.

Generic concepts

The contaminant balance was implemented by adding a code module to the code already written for the water balance (Mitchell, 1999, Mitchell and Maheepala, 1999). The water balance program loop calculates the flows through the urban water system on a daily basis. A call to the contaminant balance code at the end of this program loop utilizes the pre-calculated daily water flows to calculate the flows of contaminants through the system, (see Figure 20)

The water balance and contaminant balance operations occur sequentially for each daily time step. The water balance calculations are based on the concept of the urban volume and the fundamental unit of operation is depth in mm. The contaminant balance operations are based on the water volumes calculated in the water balance and user specified concentrations, loads and performance criteria (Figure 20).

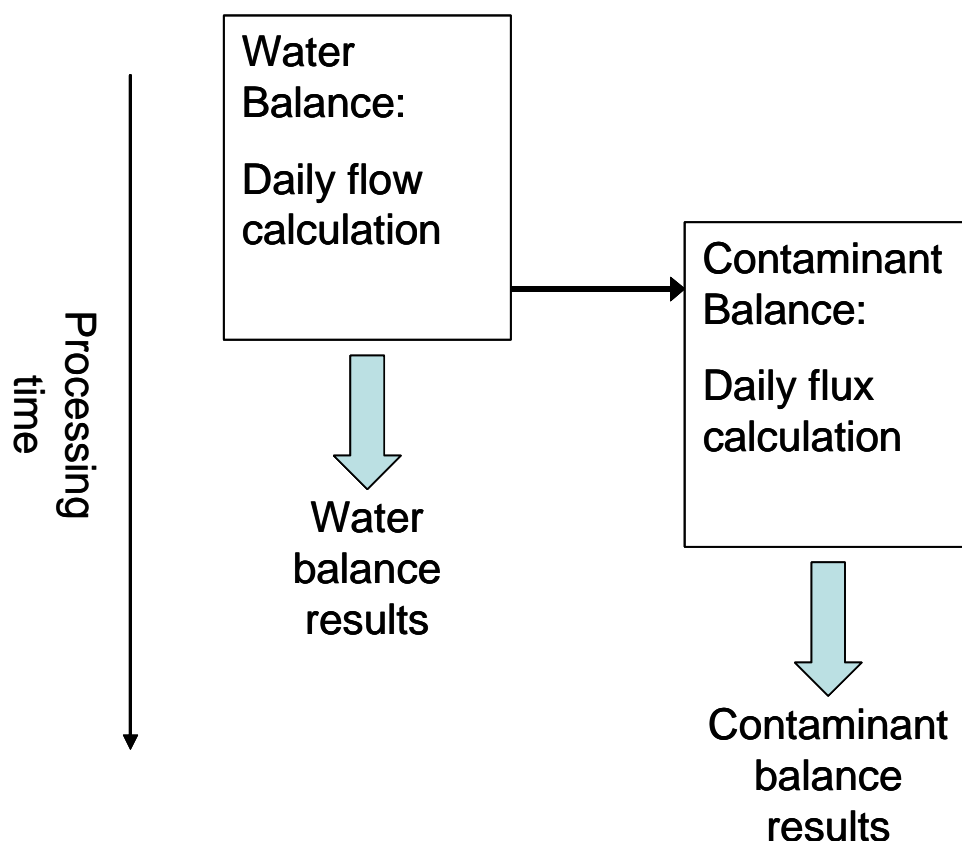


Figure 20 : Water balance and contaminant balance interaction

Thus, the contaminant balance implementation is based on the same representation of flows as the water balance, a basic representation for the conventional anthropogenic water cycle is shown in Figure 21. Full details of all the flows represented in both the water and contaminant balance are given in Appendix I: Contaminant Flow Diagrams.

Conventional water system processes

This section describes UVQ equations associated with:

- Precipitation processes
- Stormwater processes

Figure 21 illustrates the interactions between the water system processes represented in UVQ.

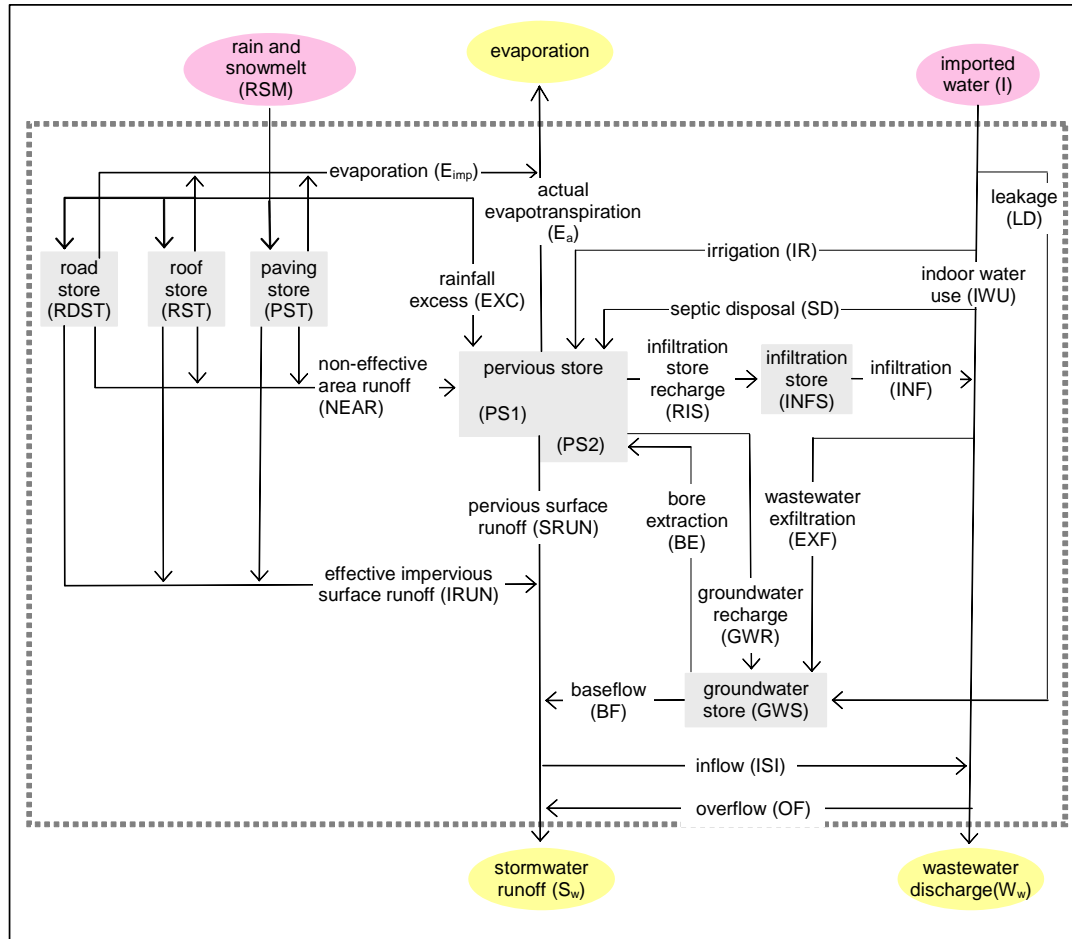


Figure 21 The conceptual representation of the urban water cycle

At land block scale (see section Spatial scales), water use, wastewater yield, stormwater runoff, and groundwater recharge processes are modelled. Information about the site, such as land use and water demands, along with daily precipitation and potential evaporation data, are required as input. The user has to specify the type of water supply and disposal system operating on the site.

At neighbourhood scale (see section Spatial scalesSpatial scales), there are a number of processes which are simulated; stormwater base flow, leakage from the reticulation system, stormwater inflow, infiltration to and exfiltration from the wastewater network, wastewater overflows and non-metered water use.

Equation notation

For some algorithms describing water flows, the minimum or maximum value calculated from a given formula is the required value. In these instances, the variables for which the calculation must be made to find a minimum or maximum value are separated by commas. For example, in the equation below, the required value of Drain_1 is the minimum value of

either $LS1_t - LS_{Fc}$ multiplied by the $Drain_{Fact}$ **or** $LS1_t - LS_{Fc}$ multiplied by the $Drain_{Max}$. This notation is used throughout the water balance algorithms.

$$Drain_1 = \min[(LS1_t - LS_{Fc}) * Drain_{Fact}, Drain_{Max}]$$

Precipitation processes

Precipitation is the amount of rain or snow that falls on an area over a specified time period. This is obtained from the climate file which is an input file to UVQ. A description of the climate file and the required format is given in Climate Input File.

Representing snowfall and snowmelt

If the simulate snow option is selected in the snow screen, UVQ converts precipitation into snow when the days mean air temperature is less than or equal to the snowfall threshold temperature specified in the snow screen. A snowfall threshold temperature of 0 °C is often used in hydrologic models that represent snow accumulation and ablation (Westerstrom, 1984).

You can specify if the snow does or does not accumulate on the roads, paved areas and roofs in the snow screen, while snow automatically accumulates on the garden and open space surfaces.

If the snow falling on these impervious surfaces does not accumulate, then it is immediately converted to snow melt, effectively becoming rain on the surface. Accumulated snow remains in the snow store of that particular surface type until it melts.

There is a separate store for each roof, paved area, garden area and open space in each neighbourhood. Figure 22 shows the snow store for a paved area.

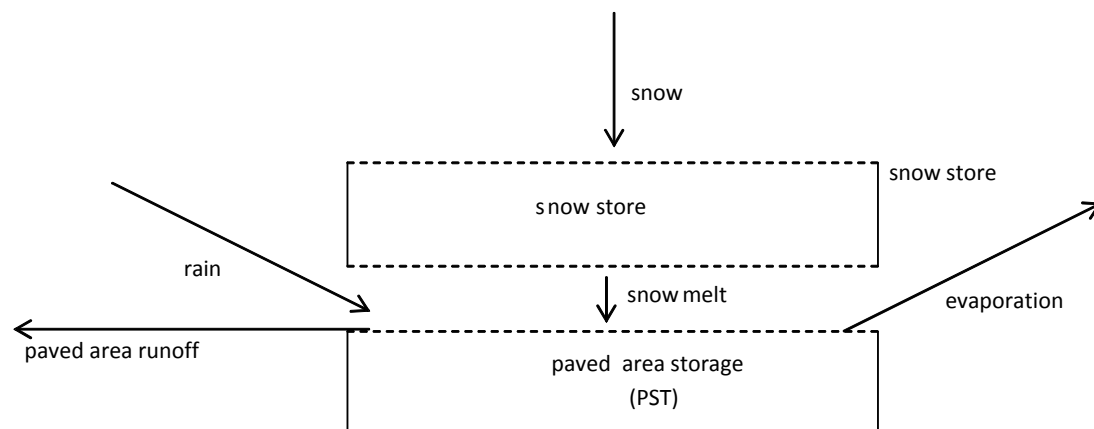


Figure 22 : Paved area snow store.

The snow melting process is driven by the snow melt threshold temperature, the melt rate factor and the average air temperature. The equation to calculate amount of snow melt is:

$$\text{Melt}_{\text{paved}} = \text{MRF} * (T - \text{SMT})$$

Melt rate factors vary depending on the condition of the snow and the local environmental conditions. The melt rate factor can range from approximately 2 to 6 mm/°C/day in sheltered forests to exposed fields, while a melt rate of 6 mm/°C/day has been reported for undisturbed clean suburban snow and 8.4 mm/°C/day for snow in a downtown park (SemáDeni-Davies *et al.*, 2000)

Stormwater is the amount of runoff discharged from a neighbourhood or study area. In UVQ, stormwater is generated from surface runoff, base flow and overflow from the wastewater system. Surface runoff is further separated into components sources from pervious and impervious surfaces due to the differing hydrological response of these surface types. Impervious surfaces can be further divided up into roofs, roads, and paved areas. Pervious surfaces include grassed areas such as lawns and parks as well as garden beds and bare soil. Therefore, four surface types are used in the model; i) pervious areas, ii) roofs, iii) paved areas, and iv) roads, with each surface generating runoff. This equation only applies at the neighbourhood scale.

Diagram illustrating the components of stormwater runoff in a separate system:

$$S_{ws} = IRUN + SRUN + BF - ISI + OF$$

Where:

- S_{ws} : stormwater runoff in a separate system
- $IRUN$: impervious surface runoff
- $SRUN$: pervious surface runoff
- BF : baseflow
- ISI : inflow
- OF : overflow

- Impervious surface runoff process
- Pervious soil store process

- Groundwater (baseflow) store process
- Inflow process
- Infiltration process

Impervious surface runoff process

Impervious surface runoff is the amount of water shed from the paving, roof or road within a neighbourhood or study area.

The equation to determine the amount of impervious surface runoff is calculated in the same way for each surface. The surface type specified in the equation changes to reflect the surface required. The paving area is used in this example.

Figure 23 illustrates the impervious surface runoff process.

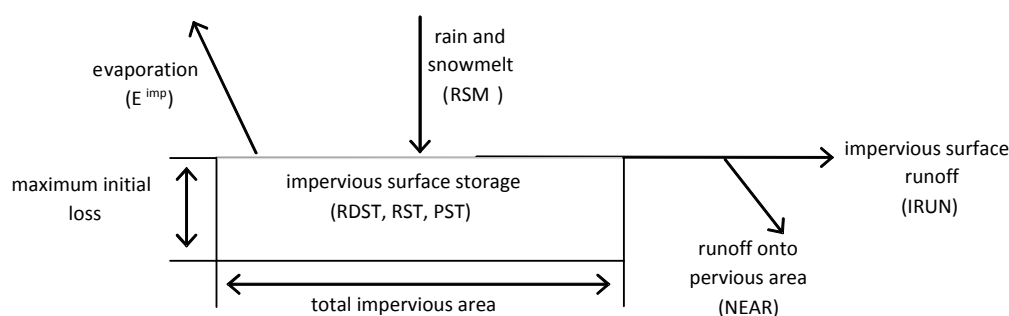


Figure 23: The impervious surface runoff process.

The equation to calculate amount of impervious surface runoff for a paved area is:

There are equivalent equations for roof and road areas.

The equations associated with the impervious surface runoff process are:

- Evaporation (E_{imp})
- Non-effective surface runoff (NEAR)
- Effective surface runoff (IRUN)

Evaporation from impervious surfaces (E_{imp})

Evaporation is the amount of water emptied from the impervious surface stores (roof, paving, and road) by evaporation. The amount of water in each surface is calculated separately and then combined according to the proportional area of each store.

The equation to calculate the impervious surface evaporation is:

Non-effective impervious surface runoff (NEAR)

Non-effective impervious area runoff is the amount of runoff from the impervious areas (roofs, paving, roads) within a neighbourhood or study area that does not drain to the

stormwater collection system and flows onto adjacent pervious surfaces (roof and paved area to garden, road to neighbourhood open space).

The impervious areas have depression storage only and no infiltration and produce surface runoff quickly during an event. The water in depression storage is lost to evaporation daily.

The equation to calculate non-effective area runoff is:

$$\begin{aligned}
 \text{NEAR} = & \underbrace{(100 - \text{ERA}/100)}_{\text{effective roof area}} * \underbrace{(\text{RS} - \text{RIL} + \text{RST})}_{\substack{\text{rain and snowmelt} \\ \text{roof area maximum initial loss} \\ \text{roof surface storage level}}} * \underbrace{(\text{roof}_{\text{area}} / \text{neigh}_{\text{area}})}_{\substack{\text{average roof area in a land block.} \\ \text{neighbourhood area}}} \\
 & + \underbrace{(100 - \text{EPA}/100)}_{\substack{\text{paved area max initial loss} \\ \text{effective paved area}}} * \underbrace{(\text{RS} - \text{PIL} + \text{PST})}_{\substack{\text{paved area surface store level}}} * \underbrace{(\text{paved}_{\text{area}} / \text{neigh}_{\text{area}})}_{\substack{\text{average paved area in a neighbourhood}}} \\
 & + \underbrace{(100 - \text{ERDA}/100)}_{\text{effective road area}} * \underbrace{(\text{RS} - \text{RDIL} + \text{RDST})}_{\substack{\text{road area maximum initial loss} \\ \text{road surface store level}}} * \underbrace{(\text{road}_{\text{area}} / \text{neigh}_{\text{area}})}_{\substack{\text{road area within a neighbourhood.}}}
 \end{aligned}$$

Effective impervious surface runoff (IRUN)

Effective impervious surface runoff is the amount of water from impervious surfaces (road, paved and roof) that contributes to the total stormwater flow.

The concept of effective impervious area has been used in several rainfall-runoff models, such as ILLUDAS (Maidment, 1993), ILLSAX (O'Loughlin, 1991), STORM (Abbott, 1977; Dendrou, 1982), and SWMM (Metcalf & Eddy Inc et al., 1971) and Aquacycle (Mitchell, 2000).

This concept is used to represent the proportion of impervious surfaces which are directly connected to the stormwater drainage system. The remainder of the impervious surfaces, which are not directly connected, drain onto adjacent pervious surfaces (see Non-effective impervious surface runoff (NEAR)).

The proportion of impervious surfaces that are directly connected to the drainage system varies greatly. In one survey of nine Australian urban catchments, Boyd et al. (1993) found that the proportion of impervious area directly connected ranged from 31% to 100%.

In UVQ, each impervious surface is modelled as a single storage runoff saturation excess process. The water retained in each store represents the initial losses due to interception and depression storage.

The equation to calculate the impervious surface runoff is:

$$\begin{aligned}
 \text{effective impervious surface runoff} &= \text{effective roof area} * (\text{rain and snowmelt} - \text{roof area maximum initial loss} + \text{roof surface storage level}) * (\text{average roof area in a land block} / \text{neighbourhood area}) \\
 &+ \text{paved area max initial loss} * \text{effective paved} * (\text{RS} - \text{PIL} + \text{PST}) * (\text{paved area} / \text{average paved area in a neighbourhood}) \\
 &+ \text{paved area surface store level} * \text{ERDA} * (\text{RS} - \text{RDIL} + \text{RDST}) * (\text{road area} / \text{road area within a neighbourhood})
 \end{aligned}$$

Labels for the equation components:

- effective impervious surface runoff
- effective roof area
- rain and snowmelt
- roof area maximum initial loss
- roof surface storage level
- average roof area in a land block
- neighbourhood area
- effective paved
- paved area max initial loss
- RS
- PIL
- PST
- paved area
- average paved area in a neighbourhood
- ERDA
- RS
- RDIL
- RDST
- road area
- road area within a neighbourhood
- effective road area
- road area maximum initial loss
- road surface storage level

Pervious soil store processes

The pervious surface runoff processes are:

- Excess Rainfall (EXC)
- Actual evaporation (E_a)
- Groundwater recharge (GWR)
- Infiltration store recharge (RIS)
- Irrigation (IR)
- Pervious surface runoff (SRUN)

Pervious soil storage is the amount of water stored within the soil profile in garden and open space areas. Because UVQ allows you to represent pervious areas using either the partial area approach or the 2 layer approach, separate processes and algorithms are required to calculate the water balance of each soil store type and the associated actual evaporation, groundwater recharge, infiltration store recharge, irrigation and pervious surface runoff.

For excess rainfall there is one algorithm describing the process for both partial area and two layer soil stores.

Excess rainfall (EXC)

Excess rainfall is the amount of run off from the two pervious storage areas (PS1 and PS2) into the stormwater system. The amount of excess soil moisture is calculated separately for each store and combined according to the proportional area of each store.

The equation to calculate the rainfall excess is:

$$\begin{aligned}
 \text{EXC} = & \left\{ \max(\text{RS} + \text{PS1} - \text{PS1}_c, 0) \right\} * A1 \\
 & + \left\{ \max(\text{RS} + \text{PS2} - \text{PS2}_c, 0) \right\} * (100 - A1)
 \end{aligned}$$

Partial area pervious soil store (PS1, PS2)

The partial area pervious soil store represents the unsaturated zone of the soil profile. The use of partial areas is based on the division of a study area into areas which produce runoff (contributing areas) and those that do not during a rainfall-runoff event (van de Griend, 1985). These contributing areas vary within a study area according to the antecedent study area conditions, allowing for the spatial variability of surface storage in a study area. The use of the partial area saturation overland flow approach is simple and provides a good representation of the physical processes occurring in most Australian catchments. Daily infiltration capacity is rarely exceeded and the major source of runoff is from saturated areas (Chiew et al., 1995).

Figure 24 illustrates this process.

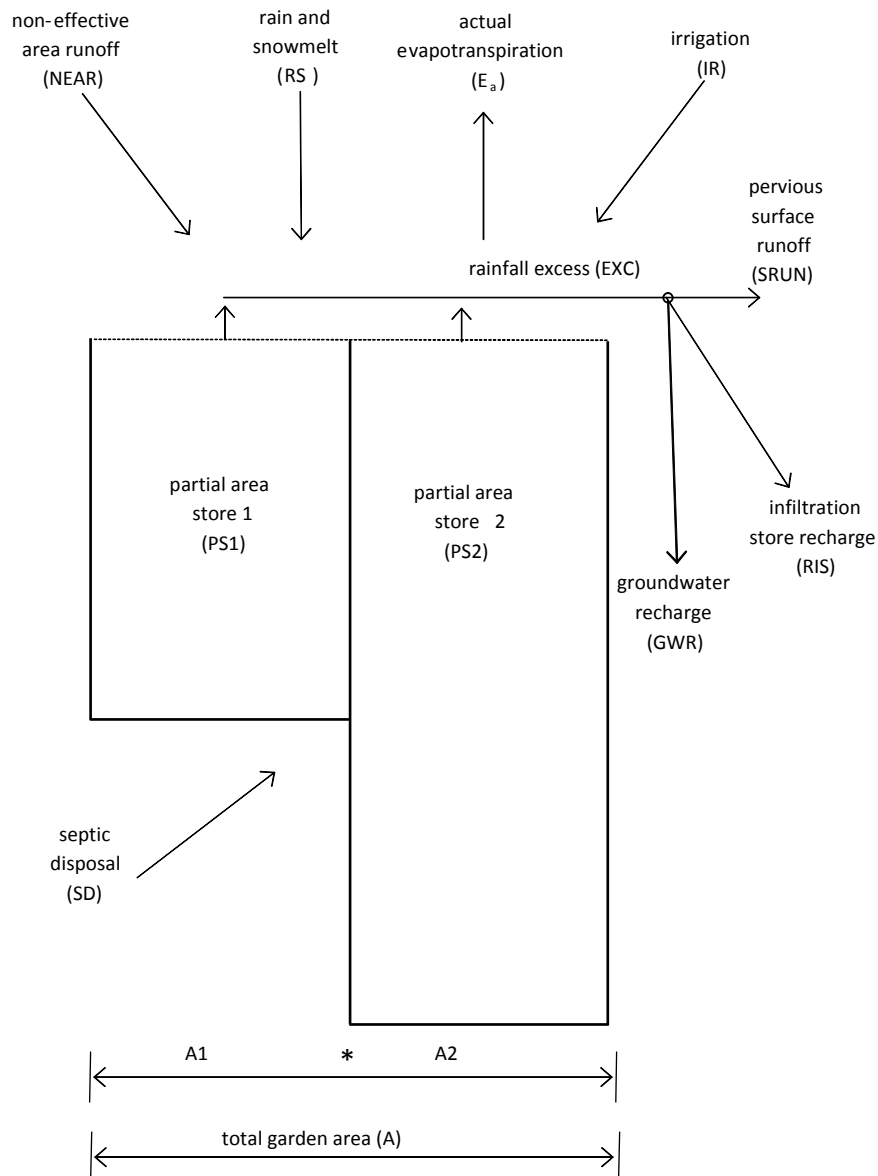


Figure 24 : Partial area surface store process.

The equation to calculate the partial area pervious soil storage status for store 1 is:

There is an equivalent equation for store 2.

Actual evapotranspiration (E_a) for partial area soil store

Actual evapotranspiration is the amount of water that evaporates from the pervious areas. The approach used to calculate actual evapotranspiration is based on work of Denmead and Shaw (1962). In the partial area approach, it is assumed that the upper limit on actual evapotranspiration is a linear function of available water in each of the stores.

The maximum amount of evapotranspiration that can occur in a given day, due to climatic conditions, is termed E_p , the potential evapotranspiration rate, and is provided as input to the model by the user in the form of the climate file (see Climate Input File). Actual evapotranspiration is calculated by UVQ to represent the amount which did actually evapotranspire in that day, given the potential rate, the soil moisture content in the pervious stores (pervious store level), and the maximum capacity of the vegetative cover to transpire (E_{pc}).

Figure 25 illustrates the calculation of the pervious surface evapotranspiration.

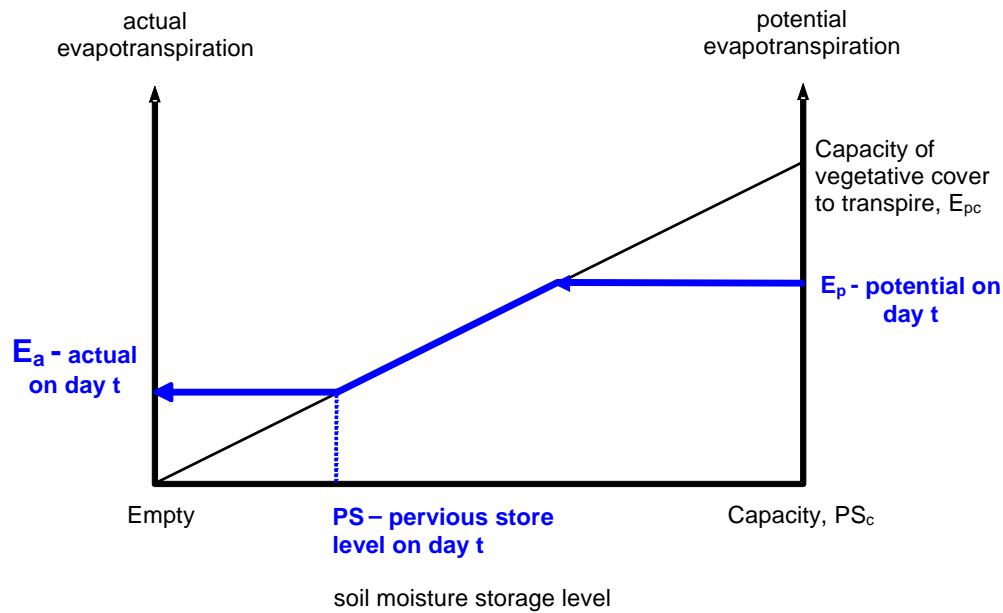
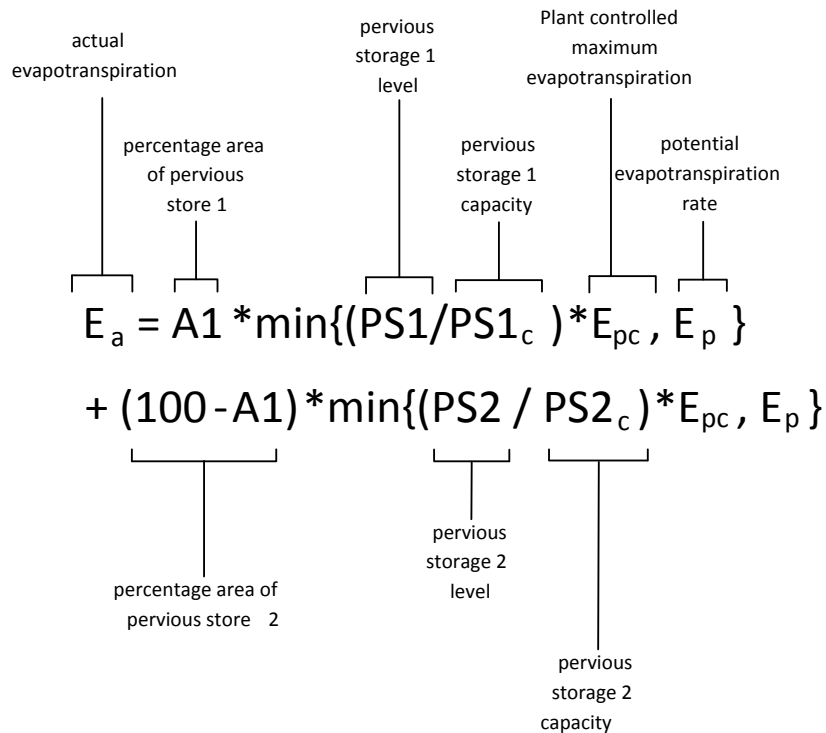


Figure 25 : The calculation of pervious surface evapotranspiration for the partial area storage method

The equation to calculate the actual evapotranspiration rate from a partial pervious area is:



Groundwater recharge (GWR) for partial area store

Groundwater recharge is the proportion of the excess soil moisture from the pervious surface store that recharges the groundwater store.

The equation to calculate groundwater recharge is:

The diagram illustrates the calculation of groundwater recharge (GWR) using the following equation:

$$GWR = BI * EXC$$

The variables in the equation are defined by the following labels:

- GWR : groundwater recharge
- BI : base flow index
- EXC : excess rainfall

Infiltration store recharge (RIS) for partial area store

Infiltration store recharge is the runoff amount that flows from the pervious soil stores into the infiltration store. This occurs during periods of excess soil moisture storage and acts as a temporary store mimicking the time delay between the rainfall event and the infiltration into the wastewater pipes. It is distinct from inflow, which occurs in the same day as the rainfall event.

A user specifies the proportion of the excess soil moisture which flows into the infiltration store via the infiltration index.

The equation to calculate the infiltration source recharge is:

$$\text{infiltration source recharge} = \text{infiltration index} * \text{excess rainfall}$$

$$\text{RIS} = \text{II} * \text{EXC}$$

Irrigation (IR) for partial area store

Irrigation is the amount of water provided to supplement precipitation to maintain the desired garden condition or growth rate. Irrigation is applied only to the pervious stores. The quantity of irrigation is a function of the water requirements of plants in the garden and the personal behaviour of the gardener. The water requirements of plants in a garden is determined by prevailing climatic conditions¹, type of vegetation contained in the garden, soil type, and the amount of area that is irrigated (Heeps, 1977; Power et al., 1981). The personal behaviour of the gardener is affected by perceived plant water need, desired garden condition, and response to cost of water. As a result, individual watering practices are extremely variable.

The decision to water a garden has been formulated as the minimum soil moisture storage level (or wetness) allowable, termed here as the trigger-to-irrigate, TG. Therefore, the model irrigates the pervious area whenever the soil moisture storage level drops below the trigger-to-irrigate.

If the soil storage level in either of the two pervious stores drops below the user defined 'trigger-to-irrigate' level then irrigation is applied to make up the deficit.

To determine the volume of water required to meet the irrigation demand, the user specifies the percentage of the total garden area and public open space area that is irrigated.

The equation to calculate the amount of irrigation applied in a given days is:

¹ Note that people respond to the weather in two ways; firstly, watering occurs after a lag period following a rain event when the gardener perceives the garden is sufficiently dry to require watering, and secondly, the gardener responds to the particular days weather with cold, cloudy, overcast days not triggering a perceived need to water (Davis, 1992).

$$IR = \max(TG * PS1_c - PS1, 0) * A1 * \%GI + \max(TG * PS2_c - PS2, 0) * (100 - A1) * \%GI$$

Pervious surface runoff (SRUN) for partial area store

Pervious surface runoff is the amount of runoff from pervious stores 1 and 2 contributing to the total stormwater flow. The amount of pervious surface runoff (SRUN) is equal to the excess soil moisture less that which goes to infiltration and that which goes to groundwater recharge.

The equation to calculate the amount of pervious surface runoff is:

$$SRUN = EXC - RIS - GWR$$

2 layer pervious soil store

This approach represents the unsaturated zone of the soil profile with an upper and lower soil store. The upper soil store receives precipitation, irrigation and non-effective area runoff inputs.

Each store has the same maximum storage depth and field capacity. Pervious surface runoff (SRUN) occurs when the upper store is full (or saturated). When water levels in the stores are between the field capacity and the maximum storage capacity, the water in each store drains downwards through the action of gravity. The upper store drains water into the

lower store, which subsequently drains into the groundwater store, representing the process of groundwater recharge. If there is insufficient spare capacity in the lower store, drainage from the upper store is limited.

If a septic disposal leach field is present a land block, the treated wastewater enters the lower soil store.

Figure 26 illustrates the pervious soil store process.

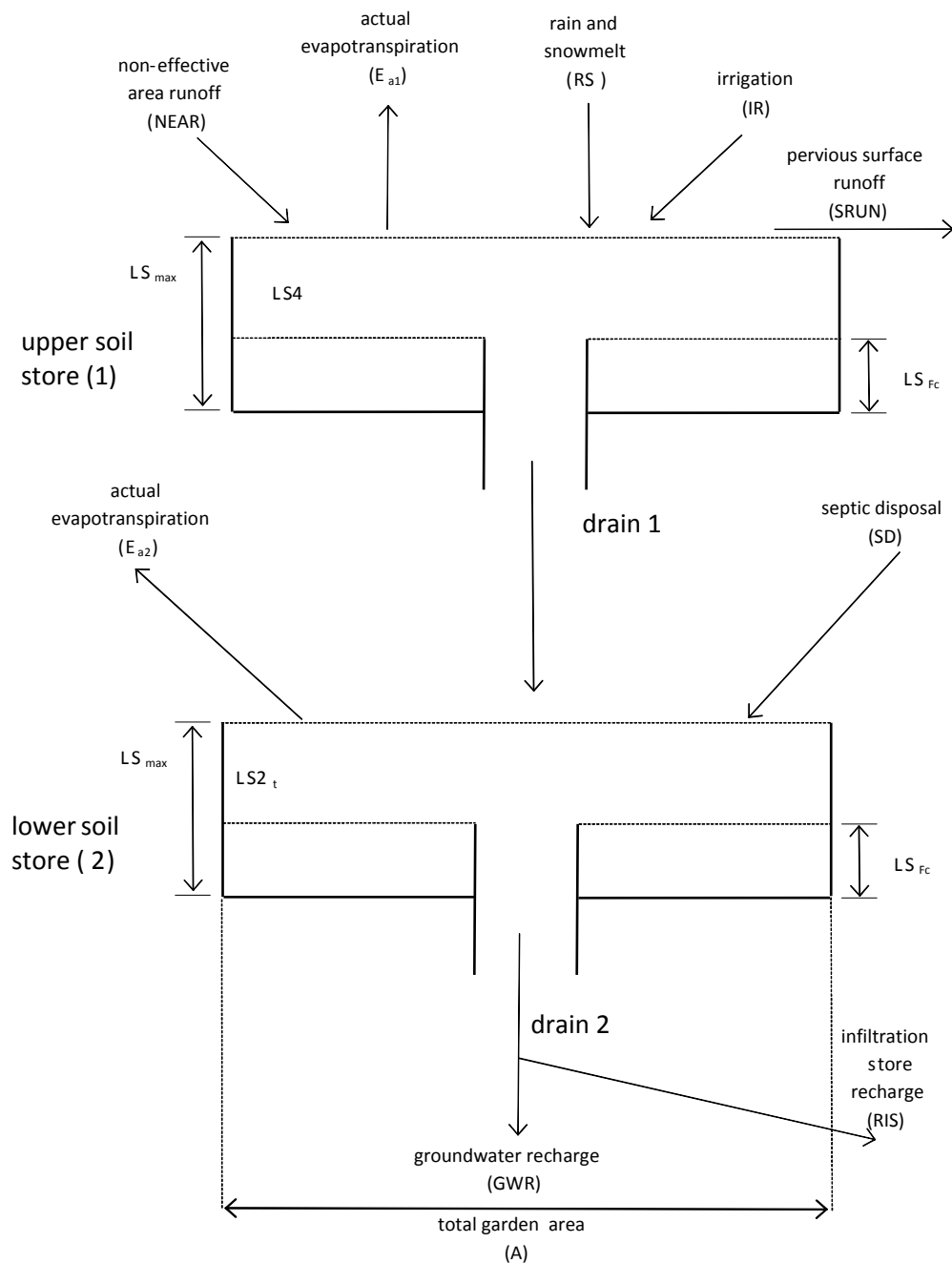


Figure 26 : Pervious soil store process.

The equation to calculate the level of water in the upper 2 layer store level is:

$$\begin{array}{c}
 \text{2 layer upper soil store level} \\
 \hline
 \text{LS1}_t = \text{LS1}_{t-1} + \text{RS} + \text{NEAR} + \text{IR} - \text{E}_{a1} - \text{SRUN} \\
 \begin{array}{ccccccc}
 & & \text{non-effective area runoff} & & \text{actual evapotranspiration} & & \\
 & & \hline & & \hline & & \hline \\
 & \text{rain and snowmelt} & & \text{irrigation} & & & \text{pervious surface runoff}
 \end{array}
 \end{array}$$

The equation to calculate the level of water in the lower 2 layer store level is:

$$\begin{array}{c}
 \text{2 layer lower soil store level} \\
 \hline
 \text{LS2}_t = \text{LS1}_{t-1} + \text{Drain1} - \text{E}_{a2} - \text{Drain2} + \text{SD} \\
 \begin{array}{ccccc}
 & & \text{lower actual evapotranspiration} & & \text{septic disposal} \\
 & & \hline & & \hline \\
 & \text{upper drainage} & & \text{lower drainage} &
 \end{array}
 \end{array}$$

Actual evaporation (Ea) for 2 layer store

Actual evapotranspiration is the amount of water that evaporates from the pervious soil stores.

The method used to calculate actual evapotranspiration is based on work of Denmead and Shaw (1962). In the 2 layer approach, actual evapotranspiration is drawn preferentially from the upper store, although if the upper store does not meet the potential demand, the remaining demand is sought from the lower store.

It is assumed that when either soil store is holding between 75% and 100% of maximum storage capacity, the upper limit on actual evapotranspiration is the maximum capacity of the vegetative cover to transpire (E_{pc}). Between 0% and 75% of maximum storage capacity, the upper limit on actual evapotranspiration is a linear function of available water in the store.

The maximum amount of evapotranspiration that can occur in a given day, due to climatic conditions, is termed E_p , the potential evapotranspiration rate, and is provided as input to the model by the user in the form of the climate file (see Climate Input File). Actual evapotranspiration is calculated by UVQ to represent the amount which did actually evapotranspire in that day, given the potential rate, the soil moisture content in the pervious stores (pervious store level), and the maximum capacity of the vegetative cover to transpire (E_{pc}).

Figure 27 illustrates the calculation of the 2 layer pervious surface evapotranspiration.

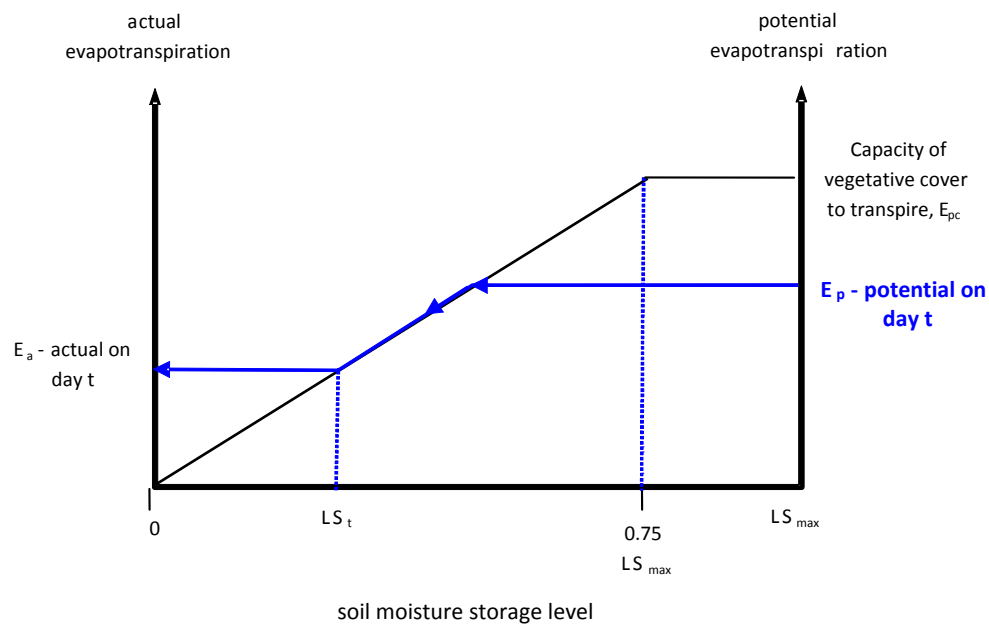


Figure 27: 2 layer pervious surface evapotranspiration calculation.

The actual evapotranspiration from each 2 layer pervious store is calculated separately, as can be seen in the equation. The equation to calculate the total actual evapotranspiration rate from a 2 layer pervious area is:

$$\begin{array}{c}
 \begin{array}{cc}
 \text{actual} & \text{lower store actual} \\
 \text{evapotranspiration} & \text{evapotranspiration}
 \end{array} \\
 \begin{array}{cc}
 \text{---} & \text{---} \\
 | & | \\
 \text{---} & \text{---}
 \end{array} \\
 E_a = E_{a1} + E_{a2} \\
 \begin{array}{c}
 \text{---} \\
 | \\
 \text{---}
 \end{array} \\
 \text{upper store actual} \\
 \text{evapotranspiration}
 \end{array}$$

Upper store actual evaporation (E_{a1})

Sources Evap from top store, LS1, first:

If $LS1_t$ is between $LS1_{max}$ and 75% of $LS1_{max}$

$$E_{a1} = \min(E_p, E_{pc}, LS1_t)$$

Else

$$E_{a1} = \min[(LS1/(0.75LS_{max})) * E_{pc}, E_p]$$

Then, if E_{a1} is less than the potential evaporation, the evaporation from the lower store is calculated.

Lower store actual evaporation (E_{a2})

If $LS2_t$ is between LS_{max} and 75% of LS_{max}

$$E_{a2} = \min(E_p - E_{a1}, E_{pc}, LS2_t)$$

Else

$$E_{a2} = \min[(LS2/(0.75LS_{max})) * E_{pc}, E_p - E_{a1}]$$

Drainage

The 2 layer pervious soil store executes drainage in the upper soil store and the lower soil store. The amount of drainage for each store is calculated separately.

Upper soil store drainage (Drain1)

When the amount of water stored in the upper soil store ($LS1$) is greater than the field capacity (LS_{Fc}), then

$$Drain_1 = \min[(LS1_t - LS_{Fc}) * Drain_{Fact}, Drain_{Max}]$$

Else

$$Drain_1 = 0$$

Where $Drain_{Fact}$ is the drainage factor as specified by the user in the Calibration Variables screen and $Drain_{Max}$ is the Maximum Daily Drainage depth as specified in Calibration Variables screen.

Lower soil store drainage (Drain1)

When the amount of water stored within the lower soil ($LS2$) is greater than field capacity (LS_{Fc}), then

$$Drain_2 = \min[(LS2_t - LS_{Fc}) * Drain_{Fact}, Drain_{Max}]$$

Else

$$\text{Drain}_2 = 0$$

Groundwater recharge (GWR) for 2 layer soil store

The equation to calculate the amount of groundwater recharge from the 2 Layer pervious store is:

Diagram illustrating the groundwater balance equation:

$$\text{GWR} = \text{Drain} - \text{RIS}$$

Where:

- GWR** (Groundwater Recharge) is the difference between **Drain** and **RIS**.
- Drain** (Drainage amount from lower soil store) is the difference between **infiltration store recharge** and **groundwater recharge**.

Infiltration store recharge (RIS) for 2 layer soil store

Infiltration store recharge is the runoff amount that flows from the pervious soil stores into the infiltration store. This occurs during periods of excess soil moisture storage and acts as a temporary store mimicking the time delay between the rainfall event and the infiltration into the wastewater pipes. It is distinct from inflow, which occurs in the same day as the rainfall event.

A user specifies the proportion of water draining from the lower soil store which flows into the infiltration store via the infiltration index.

The equation to calculate the amount of infiltration source recharge from a 2 layer pervious soil store is:

infiltration
store recharge

drainage
amount from
lower soil store

$$RIS = II * Drain$$

infiltration
index

Irrigation (IR) for a 2 layer soil store

Irrigation is the amount of water provided to supplement precipitation to maintain the desired garden condition or growth rate. Irrigation is applied only to the pervious stores. The quantity of irrigation is a function of the water requirements of plants in the garden and the personal behaviour of the gardener. The water requirements of plants in a garden is determined by prevailing climatic conditions², type of vegetation contained in the garden, soil type, and the amount of area that is irrigated (Heeps, 1977; Power et al., 1981). The personal behaviour of the gardener is affected by perceived plant water need, desired garden condition, and response to cost of water. As a result, individual watering practices are extremely variable.

Irrigation is applied to the upper soil store when the storage level drops below the user defined “trigger-to-irrigate” level, in order to make up the deficit.

To determine the volume of water required to meet the irrigation demand, the user specifies the percentage of the total garden area and public open space area that is irrigated.

The equation to calculate the amount of irrigation in a 2 layer pervious soil store is:

$$IR = [\max(TG * LS_{\max} - LS_{1_t}, 0)A * \%GI]$$

The diagram includes the following labels and connections:

- irrigation**: A bracket above the entire equation.
- actual upper store level**: A bracket above LS_{1_t} .
- maximum upper store level**: A bracket below LS_{\max} .
- total garden area**: A bracket below A .

Pervious Surface Runoff (SRUN) for a 2 layer soil store

SRUN is the amount of water overflowing from the upper soil store which subsequently contributes to the total stormwater flow from the neighbourhood.

The equation to calculate the amount of pervious surface runoff from a 2 layer pervious store is:

² Note that people respond to the weather in two ways; firstly, watering occurs after a lag period following a rain event when the gardener perceives the garden is sufficiently dry to require watering, and secondly, the gardener responds to the particular days weather with cold, cloudy, overcast days not triggering a perceived need to water (Davis, 1992).

$$\text{SRUN} = \max(\text{LS1}_t - \text{LS1}_{\max}, 0)$$

pervious surface runoff

upper pervious store water capacity

upper pervious store water level

Groundwater process

The equations associated with the groundwater process are:

- Ground water store (GWS)
- Baseflow (BF)

Groundwater storage (GWS)

Groundwater storage is the amount of water held in aquifers below the ground surface and represents the saturated zone of the soil profile.

The equation to calculate the groundwater storage is:

$$\text{GWS}_t = \text{GWS}_{t-1} + \text{GWR} + \text{LD} - \text{BF} - \text{BE} - \text{EXF}$$

groundwater storage

groundwater storage level of previous day

groundwater recharge

leakage

base flow from imported water

bore extraction

wastewater exfiltration

Baseflow (BF)

Base flow is the amount of water drained from the groundwater store that contributes to the total stormwater flow. The groundwater store is drained according to a recession function, creating base flow.

The equation to calculate the base flow is:

base flow
recession
constant

base flow

groundwater
storage level

$$BF = BRC * GWS$$

Inflow (ISI) process

Inflow is the amount of stormwater that flows into the wastewater system rapidly due to poor or aged drainage infrastructure. The inflow amount is represented as a proportion of the total surface runoff generated.

The equation to calculate the inflow is:

inflow

percentage
of surface
flow as inflow

pervious
surface
runoff

impervious
surface runoff

$$ISI = \%I * (SRUN + IRUN)$$

Infiltration (INF) process

Infiltration is the amount of water from the temporary infiltration store that drains into the wastewater system.

The equation to calculate the infiltration amount is:

infiltration
recess
constant

infiltration

infiltration
store

$$INF = IRC * \sqrt{INFS}$$

Infiltration storage (INFS)

Infiltration storage is the amount of water contained within a temporary infiltration store. This water drains into the wastewater system.

The equation to calculate the infiltration store level is:

$$\text{INFS}_t = \text{INFS}_{t-1} + \text{RIS} - \text{INF}$$

Imported water supply processes

In a conventional system, all imported water supply would be provided through the potable pipe system supplying all indoor and outdoor irrigation uses, as well as leakage occurring from the pipes. Total water use is separated into indoor and irrigation components.

The equation to calculate the amount of imported water is:

$$I = IWU + IR + LD - BE$$

The imported water processes are:

- Indoor water usage (IWU)
- Leakage
- Irrigation
- Bore extraction

Note that a system which uses stormwater and/or wastewater as supply sources will use less imported water, with additional terms included in the above equation.

Indoor water usage (IWU)

Indoor water usage is the volume of water used in an urban area and subsequently transformed into wastewater. Water in residential and non-residential land blocks is used for different purposes and so the approach used to determine the volume of water also differs.

Indoor use is disaggregated into components: kitchen, bathroom, laundry, and toilet and the user specifies water usage in the interface for each neighbourhood for these four end uses, in the units L/c/d (litres per capita per day).

- Kitchen (K_n)
- Bathroom (B_n)
- Laundry (L_n)
- Toilet (T_n)

The user also specifies the average occupancy (Occ_n) and the number of land blocks in the neighbourhood (NLB_n).

The equation to calculate the amount of indoor water use is:

$$IWU_n = (K_n + B_n + L_n + T_n) * Occ_n * NLB_n$$

Diagram illustrating the components of the indoor water use equation:

- IWU_n : indoor water usage of neighbourhood number n
- K_n : kitchen
- B_n : bathroom
- L_n : laundry
- T_n : toilet
- Occ_n : average occupancy
- NLB_n : number of land blocks in the neighbourhood
- n : neighbourhood number

If the user would like represent a land use other than residential, they can mimic the non-residential indoor land block water usage by altering either the occupancy (Occ_n) or one or more of the end users (K_n, B_n, L_n, T_n). The important thing to note is that the 'toilet' end use is the only indoor one that can be supplied by the:

- On-site wastewater treatment unit store
- Neighbourhood stormwater and wastewater store
 - Study area stormwater and wastewater store

So, if you want to mimic a non-residential land block such as an industrial operation which has a large demand for sub-potable water for cooling purposes, this indoor demand should be represented by setting $T_n * Occ_n$ to equal the appropriate L/d value.

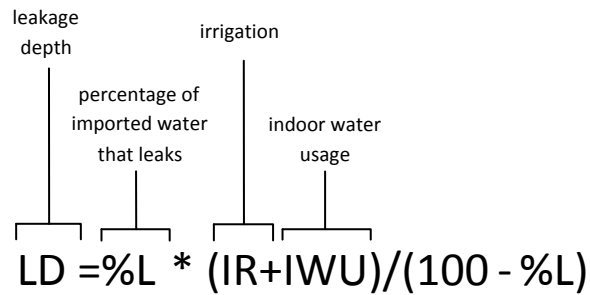
Leakage (LD)

Leakage is the amount of water that leaks from the imported water system into the groundwater store.

Leakage from a reticulation system varies due to the care exercised in construction and its maintenance, age and condition. The condition of the reticulation system is affected by soil movement, corrosive conditions, pipe material, workmanship, age, supply pressure, number of joints and connections, and the occurrence of bursts/cracks due to overburden loading or water hammer (Heeps, 1977).

In UVQ, leakage of the reticulation system is assumed to be proportional to the bulk water use ($IR + IWU$) of an area.

The equation to calculate leakage is:



$$LD = \%L * (IR + IWU) / (100 - \%L)$$

Bore extraction (BE)

Bore extraction represents the pumping of water from the groundwater store for irrigation purposes.

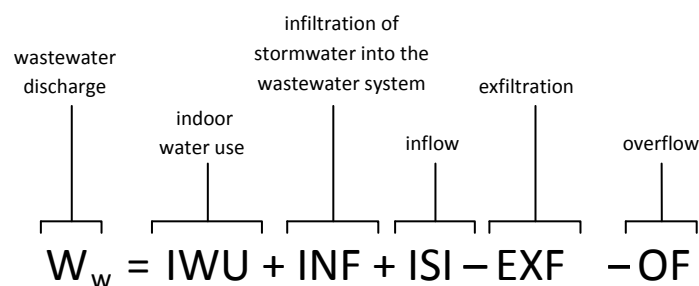
Wastewater generation processes

The processes associated with wastewater generation are:

- Wastewater discharge (W_w)
- Wastewater exfiltration (EXF)
- Overflow (OF)
- Infiltration (INF)
- Inflow (ISI)
- Septic Disposal (SD)

Wastewater discharge (W_w)

Wastewater discharge is the amount of wastewater discharged from an area. The equation to calculate the amount of wastewater discharge is:



$$W_w = IWU + INF + ISI - EXF - OF$$

Wastewater Exfiltration (EXF)

Wastewater exfiltration is the amount of wastewater leaking out of the wastewater pipes due to cracks and breaks. It flows into the groundwater store.

The equation to calculate the amount of wastewater exfiltration is:

The diagram shows the components of the EXF equation. Above the equation, vertical lines connect the following terms to their respective parts of the formula: 'wastewater exfiltration' to 'EXF', 'exfiltration rate' to 'ExRate', 'indoor water usage' to 'IWU', 'inflow' to 'INF', 'infiltration' to 'INF', and 'septic disposal' to 'SD'.

$$EXF = ExRate * (IWU + ISI + INF - SD)$$

Overflow (OF)

Overflow can occur during dry weather and wet weather via different mechanisms. During dry weather overflow occurs due to breaks in the pipes and cracks caused by big tree roots etc. Overflow also occurs due to the wastewater flow exceeding the capacity of the system conveying the wastewater. This can happen during wet weather, but also happens when the system reaches capacity for other reasons.

The equation to calculate the overflow is:

The diagram shows the components of the OF equation. Above the equation, vertical lines connect the following terms to their respective parts of the formula: 'overflow' to 'OF', 'overflow during dry weather' to 'OF_{dry}', and 'overflow during wet weather' to 'OF_{wet}'.

$$OF = OF_{dry} + OF_{wet}$$

Dry weather overflow (OF_{dry})

The equation to calculate the dry weather overflow is:

The diagram shows the components of the OF_{dry} equation. Above the equation, vertical lines connect the following terms to their respective parts of the formula: 'dry weather overflow' to 'OF_{dry}', 'overflow' to '%OF', 'indoor water usage' to 'IWU', 'inflow' to 'INF', 'infiltration' to 'INF', and 'wastewater exfiltration' to 'EXF'.

$$OF_{dry} = \%OF * (IWU + ISI + INF - EXF)$$

Wastewater System Capacity overflow (OF_{wet})

(Formerly labelled wet weather overflow)

The equation to calculate the Wastewater System Capacity overflow is:

$$OF_{wet}^{min} = ((IWU + ISI + INF - EXF) - W_{wcap}), 0)$$

Septic Disposal

Septic disposal occurs when a septic tank and leach field is used to treat and dispose of the wastewater generated within a land block. The wastewater is added to the soil stores.

Contaminant operations

The contaminant concentrations and loads in UVQ track the flow paths calculated in the water balance. The user provides specified contaminant concentrations or loads for the flow paths and contaminant input points as shown in Table 1.

Table 1 : Specified contaminants and their units

	User specified contaminants
Bathroom	mg/c/d
Kitchen	mg/c/d
Toilet	mg/c/d
Laundry	mg/c/d
Imported water	mg/l
Rainfall	mg/l
Pavement runoff	mg/l
Roof runoff	mg/l
Road runoff	mg/l
Fertiliser to POS	mg/l
Evaporation	mg/l
Ground water	mg/l
Roof first flush	mg/l

The contaminants to be investigated are selected by the user. Selection will depend upon the purpose of the modelling simulation.

The removal of a specific contaminant through a soil store or treatment process is user specified and so distinction can be made between removal efficiencies for different contaminants. For example an on-site wastewater system (septic tank) will remove a high percentage of suspended solids and the user can specify a 70% removal efficiency for this contaminant. However, an on-site wastewater treatment process (septic tank) will not remove a high percentage of nitrogen and the user can specify a lower removal efficiency (30%). Suggested removal efficiencies for specific wastewater treatment processes can be found in Metcalf and Eddy (1991) and for stormwater processes see Australian Runoff Quality (2004).

There are three basic contaminant balance calculations, use, mix and sludge calculation, and all contaminants are modelled using the same operations in UVQ.

Use operation

In this operation contaminant **concentrations** from one stream are directly transferred to other streams and this operation is used to represent streams that have identical concentrations. For example the contaminant concentration in imported water to the land

block is the same as imported water to the toilet, kitchen, bathroom, laundry, garden and public open space.

$$C_l = C_k = C_b = C_l = C_t = C_g = C_{POS}$$

Where C is the concentration of any given contaminant and the subscripts l, k, b, l, t, g and POS refer to imported water, kitchen, bathroom, laundry, toilet, garden and public open space input water supplies respectively.

Mix operations

Mix operations combine the contaminant **loads** for multiple input streams and calculate a summed load output which is associated with the volume provided by the water balance, thus producing a concentration. It is assumed that there is no accumulation or destruction of mass or water anywhere in the mix. An example of a mix operation is the wastewater output from a land block where outputs from the toilet, laundry, bathroom and kitchen are mixed. Thus the load of contaminant 1, C1, from the land block wastewater (LB WW) output mix operation, LB WW Load C1, can be expressed as:

$$V_k C1_k + V_b C1_b + V_l C1_l + V_t C1_t = \text{LB WW Load C1}$$

Where V is the volume or flow and C1 is the concentration of contaminant 1 associated the kitchen, bathroom, laundry or toilet flow paths respectively. The calculated output load is associated with a flow calculated from the water balance and thus the concentration of the mixed flow path can be calculated. The process will be repeated for all contaminants C1 to Cn.

Sludge operations

Sludge operations allow for the mixing of multiple input contaminant profiles, the production of multiple output contaminant profiles and the removal of contaminants. Sludge operations are used to;

- model treatment processes,
- calculate contaminants removed by soil stores,
- predict input loads to impervious surfaces
- track differences in known contaminant loads.

As a general rule a sludge operation is used where there is loss or addition of contaminants from the water system.

There are two types of sludge operation: the simple sludge operation in which the input and output contaminant profiles are known and the process is assumed to have no volume, and the complex sludge in which outputs streams may be unknown and the process is assumed to have some volume which may retain contaminants.

Simple sludge

In the simple sludge operation both input and output contaminant profiles are known, either because they are specified or calculated from previous operations. For simple sludges the process is assumed to have no volume and there is no given efficiency for the process.

The simple sludge operation is used for two purposes, to calculate the accumulation of contaminants within a process in which input and output streams are specified or to provide an estimation of the possible additional load of contaminants to a process. Three cases in UVQ where the simple sludge operation is used to provide an estimation of additional contaminants are the pavement, roof and road assumed loads (see Results Cont Bal – Neighbourhood N.csv where N is the neighbourhood). A diagram representing the flows of contaminants to the road area is shown below (Figure 28). There is similar representation of pavement and roof assumed loads.

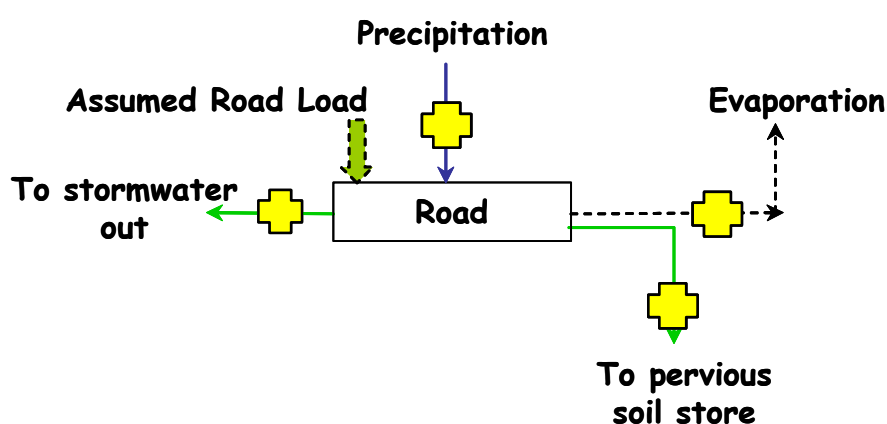


Figure 28: Flows of contaminants to and from the road area

As the contaminants in all input and output streams are specified in the user interface the simple sludge operation calculates the difference between the input and the outputs to provide a value for an assumed load to the road surface. The value for the assumed road load will be negative if unknown contaminants are being added to the road surface or positive when the road surface removes contaminants from the input streams.

Thus the assumed road load $ARoad_{LC1}$ for contaminant 1 is calculated by:

$$ARoad_{LC1} = P_{LC1} - Evap_{LC1} - PSS_{LC1} - SSys_{LC1}$$

Where P is precipitation, Evap is evaporation, PSS is pervious soil store and Ssys is the stormwater system. The subscript LC1 refers to loads for contaminant 1. The process will be repeated for all contaminants.

All cases of simple sludge operations are shown in Table 2.

Table 2 : Simple sludge operations in UVQ

Description and location	Spatial scale
Pavement	Land block
Roof	Land block

Description and location	Spatial scale
Ground water store	Land block
Road	Neighbourhood
Ground water store	Neighbourhood

Complex sludge

In the complex sludge operation input contaminant profiles are known, (because they are specified or calculated from previous operations) but not all output contaminant profiles are known and the complex sludge operation calculates them. For complex sludges the process has a user specified maximum volume and there is a user specified process efficiency.

The complex sludge operation is used to calculate the accumulation of contaminants within a process of a given efficiency and to calculate the load and concentration of unknown output streams. An example of a complex sludge operation in UVQ is the on-site wastewater treatment system. A diagram representing this system is shown below (Figure 29). The only user specified input is the first flush from the roof. The kitchen, laundry, bathroom, toilet input is calculated from a mix operation as specified above.

The complex sludge operation assumes a retained volume (as specified in the user interface) and associated contaminants. The incoming streams are mixed with this treatment volume before the compositions of the output streams are calculated. Users can specify an initial volume or storage level retained in the treatment processes.

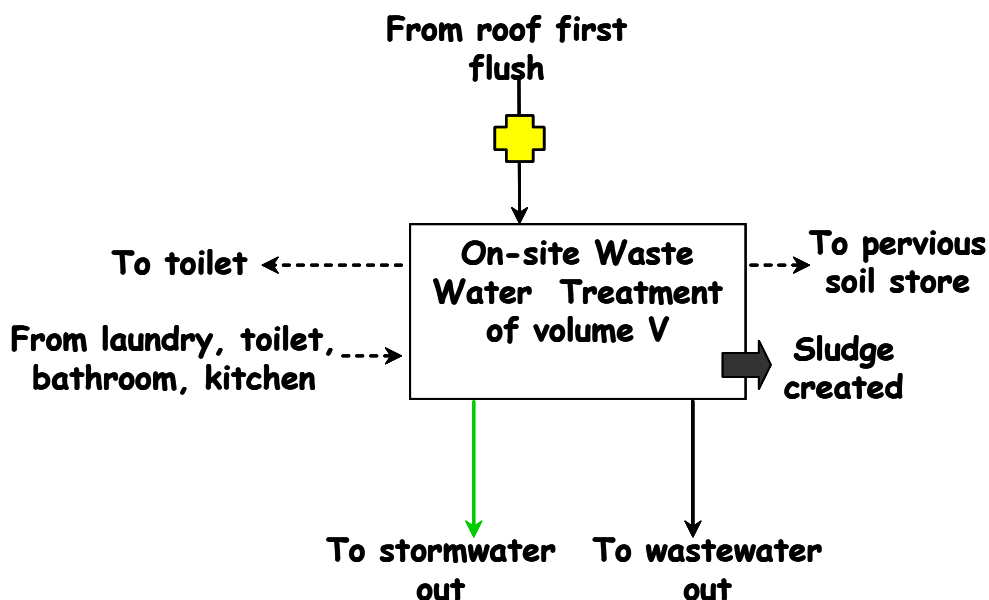


Figure 29 : Flows of contaminants to and from the on-site wastewater treatment process

The contaminant profile of the retained volume is equivalent to the calculated profiles of the mixture and will vary daily, depending on the input loads of contaminants. Retained volume at day one is as specified in the user interface. However, at day one it is assumed that there

are no contaminants in the store. The volume of the treatment process has a user specified maximum (storage capacity of on-site wastewater unit in the Land Block tab of the user interface) and the retained volume will always be below this limit. Upon exceeding this maximum value the water and contaminants in the treatment process overflow or spill to the output streams. The volumetric flows of the output streams are calculated by the water balance.

For the on-site wastewater treatment unit the load of contaminant C1 in the treatment process ($OnWWT_{mix_{LC1}}$) will be calculated as follows:

$$OnWWT_{mix_{LC1}} = RFF_{LC1} + L_{LC1} + B_{LC1} + T_{LC1} + K_{LC1} + Rv_{LC1\ t-1}$$

Where RFF is roof first flush, L is laundry, B is bathroom, T is toilet, K is kitchen, Rv_{t-1} is retained volume of previous day and the subscript LC1 refers to the load of contaminant 1. The calculated load is present in the volume calculated from the water balance.

The sludge removal calculation is then carried out for contaminant C1, where % removal efficiency of the process (%RemEff) is specified by the user in the land block tab in the user interface:

$$OnWWT_{out_{LC1}} = OnWWT_{mix_{LC1}} \times (1 - \%RemEff)$$

From the above total load of contaminant 1 and the water balance pre-calculated volumes of pervious soil store, stormwater and wastewater output streams, the concentration of contaminant C1 in the output streams ($OnWWT_{mix_{CC1}}$) and the in the current days retained volume can be calculated.

$$OnWWT_{out_{CC1}} = OnWWT_{out_{LC1}} / (Output + R_v)$$

In the example of the on-site wastewater treatment system all output streams contaminant concentrations are calculated and all will have the same value. However, if specified output streams are present, such as evaporation, these are removed from the treatment before the mixture load is calculated.

All cases of complex sludge operations are shown in Table 3

Table 3 : Complex sludge operations in UVQ

Description and location	Spatial scale
Pervious soil store	Land block

Rain tank	Land block
On-site waste water treatment	Land block
Pervious soil store	Neighbourhood
Neighbourhood Stormwater store	Neighbourhood
Neighbourhood Wastewater store	Neighbourhood
Study area Stormwater store	Study area
Study area Wastewater store	Study area

Retained volumes

The retained volumes and associated contaminants for all the processes represented in UVQ that use a complex sludge operation are all included in the mix of input loads. The previous day's contaminants that are present in the store of treatment process are added to the mix prior to the sludge operation being carried out.

Contaminant operations between spatial scales

As with water balance flows, contaminants flow between the three spatial scales represented in UVQ; the land block, the neighbourhood and the study area. The diagrams representing all possible flow paths in UVQ show flow to and from alternative water servicing options such as; raintanks, on-site wastewater treatment processes, neighbourhood and study area stormwater and wastewater stores. In addition all the standard flow paths are represented, such as groundwater, infiltration, soil stores and irrigation. In this section of the manual particular portions of the complex flow diagrams are presented in order to provide the user with understanding of the flows between spatial scales and the range of flows represented. Full flow diagrams representing all these flows are given in Appendix I: Contaminant Flow Diagrams.

All contaminant streams have a distinct stream number which identifies them within the contaminant code. The stream numbers relate to the specific volume, load and thus concentration for each contaminant specified by the user. These stream numbers are used in the following diagrams in order to allow the user to track paths in Wizard Results Interface (Results).

The following diagrams and explanations describe all input and output contaminant loads and concentrations from individual processes represented in UVQ. Not all the inputs and outputs represented will be calculated for every UVQ modelling simulation as streams will be switched on and off by user specified choices. The numbers signify the stream identifier and streams marked with a yellow cross are those which are specified, either directly by the user or by a use operation.

Notation

Rainwater tank

The rainwater tank collects flows and their associated contaminants from the roof (specified) and the neighbourhood wastewater and stormwater stores (calculated). There is no potable backup represented to the rain tank. If there is no water to supply the user specified end uses then these demands will be met with imported water. Within the rainwater tank contaminants from the input streams are mixed, user specified removal occurs and the sludge load calculated, a volume and associated contaminants is retained and the remaining contaminant load in the output streams is calculated. The rainwater tank can supply indoor uses (kitchen, bathroom, laundry and toilet) and the land block garden. Overflow is directed to the neighbourhood stormwater system. The contaminant concentration in all rainwater tank output streams and in the retained volume will be the same.

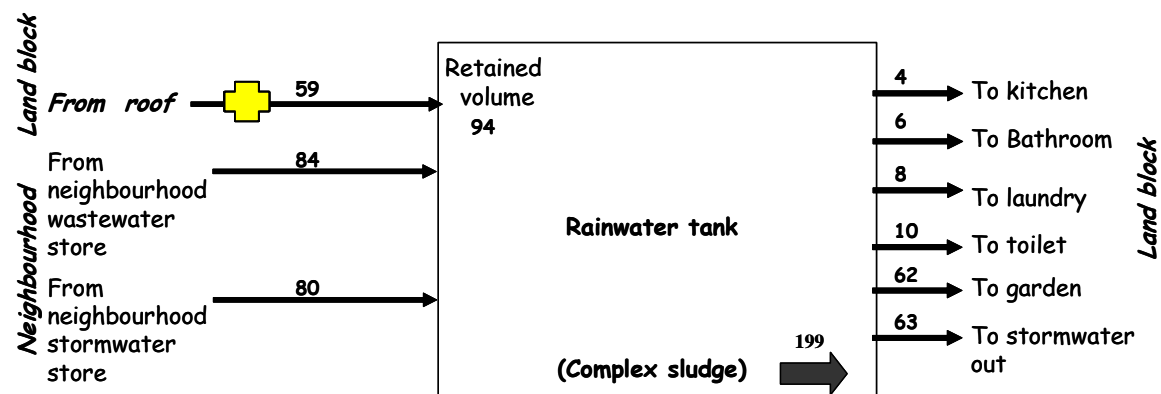


Figure 30 – Rainwater tank contaminant inputs and outputs

On site wastewater store/treatment

The on site wastewater store or treatment process collects wastewater from the kitchen, bathroom, toilet and laundry. Within the on site wastewater store contaminants are mixed, user specified removal occurs and the sludge load is calculated. A volume and associated contaminants is retained and the remaining contaminant load and concentration in output streams is calculated. The contaminant concentration in all output streams will be the same. The on site wastewater store can supply the garden (either through a leachfield or irrigation) and the toilet. The overflow is directed to either the neighbourhood wastewater or stormwater system.

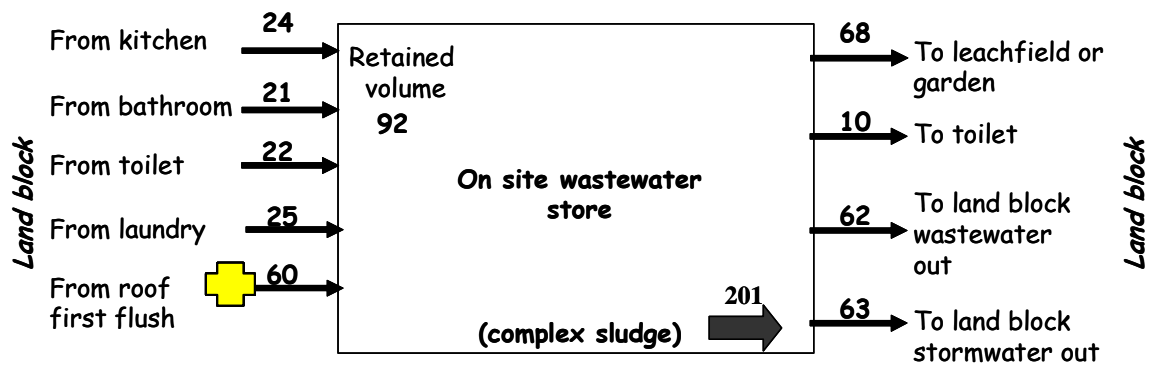


Figure 31 – On site wastewater store contaminants inputs and outputs

Garden pervious soil store

In order to represent contaminant fluxes to and from the garden pervious soil store, the store is split into surface and subsurface operations. Raintank, roof (specified), pavement and tap (specified) flows from the land block are all inputs to the top pervious soil store along with stormwater, wastewater and groundwater stores (specified) from the neighbourhood and flows from study area stormwater and wastewater stores. Precipitation and (specified) and any fertiliser load (specified) are also inputs. All these contaminants are mixed and the load of contaminants from the surface to the subsurface is calculated. This load is split between the flow to runoff and the flow to subsurface to give two streams with equal concentration. The subsurface flow then mixes with any loads associated with land block treatment or reuse processes, either greywater or on site wastewater streams. Any contaminant load associated with evaporation (specified) is subtracted and then the sludge load is calculated from the user specified soil store removal efficiency. Once the sludge is calculated remaining contaminants are either retained within the soil store or flow to infiltration or groundwater stores. The calculated concentration of these two streams (71 and 72) will be the same.

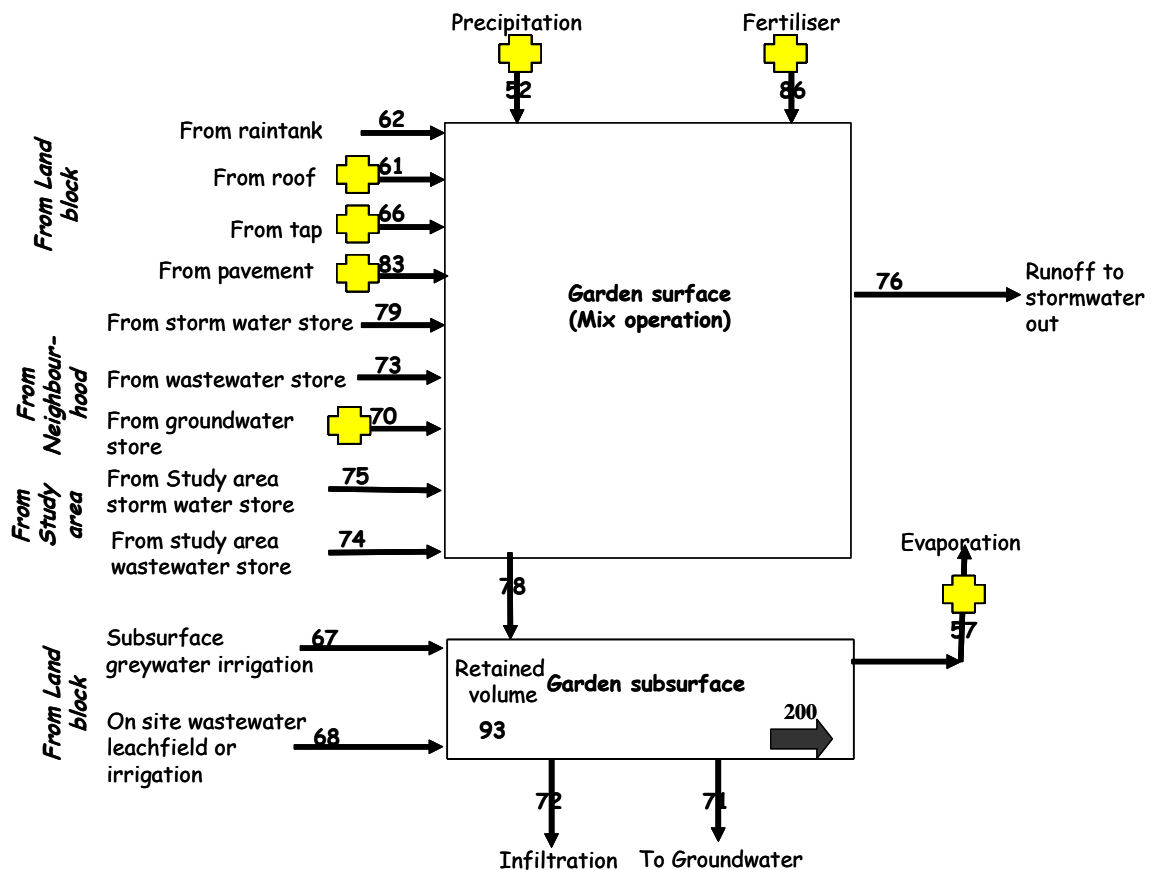


Figure 32 – Garden pervious soil store contaminants inputs and outputs

Public open space

In order to represent contaminant fluxes to and from the open space pervious soil store, the store is split into surface and subsurface operations. Precipitation (specified) and any fertiliser load (specified) and neighbourhood scale imported water irrigation, road runoff, stormwater and wastewater stores and groundwater store (specified) are all possible inputs to the surface store. In addition flows from the study area stormwater and wastewater stores are added. From this mix operation the load of contaminants from the surface is calculated. This load is split between the flow to surface runoff and the flow to subsurface to give two streams with equal concentration. Any contaminant load associated with evaporation (specified) is subtracted from the subsurface flow and then the sludge load is calculated from the user specified soil store removal efficiency. Once the sludge is calculated and the contaminants are removed from the store, remaining contaminants are either retained within the soil store or flow to infiltration or groundwater stores. The calculated concentration of these two streams (117 and 113) is the same.

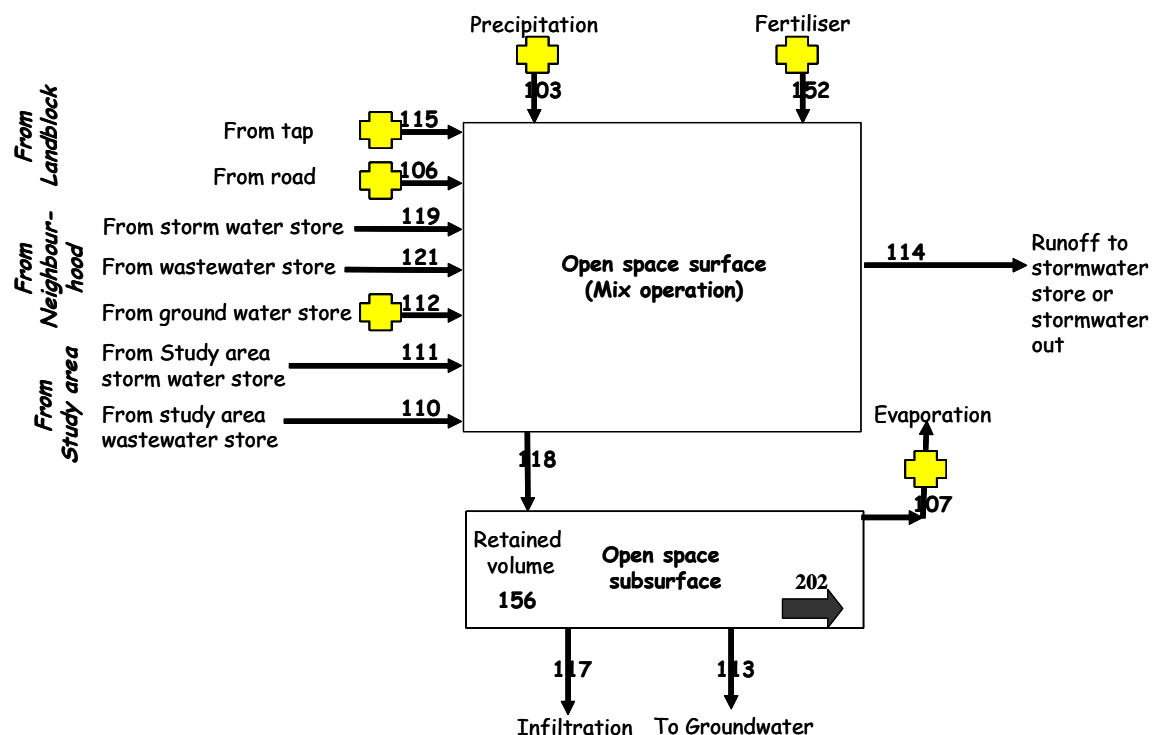


Figure 33 – Public open space soil store contaminant inputs and outputs

Neighbourhood stormwater store/treatment

Flows and contaminants to the neighbourhood stormwater store can originate from the following stormwater runoff sources;

- Land Blocks
- Public open space,
- Roads (specified)
- Overflow from the wastewater store within the neighbourhood.
- Flows from other neighbourhoods
- Precipitation to the surface of the store

The user specifies which sources are collected.

All these contaminants loads are mixed within the store and any load associated with the evaporation stream (specified) is subtracted. The stormwater store sludge is then calculated based on the user specified removal efficiency. The appropriate removal efficiency specified will depend on the contaminant and the type of process being modelled. For example if a simple retention basin is being represented removal of suspended material will be between 40 and 60%. If a higher level of treatment is assumed i.e. microfiltration, then up to 100% of suspended material will be removed. Some suggested values for removal efficiencies of different process for different contaminants are given in Australian Runoff Quality (2004).

Once the calculated sludge load is removed from the contaminants in the store, the remaining contaminants are either retained within the stormwater store or flow to the land block toilet, raintank or garden, the neighbourhood public open space, groundwater or overflow to stormwater or sewer. The user specifies which end uses are operational. The calculated concentration of all output streams will be the same.

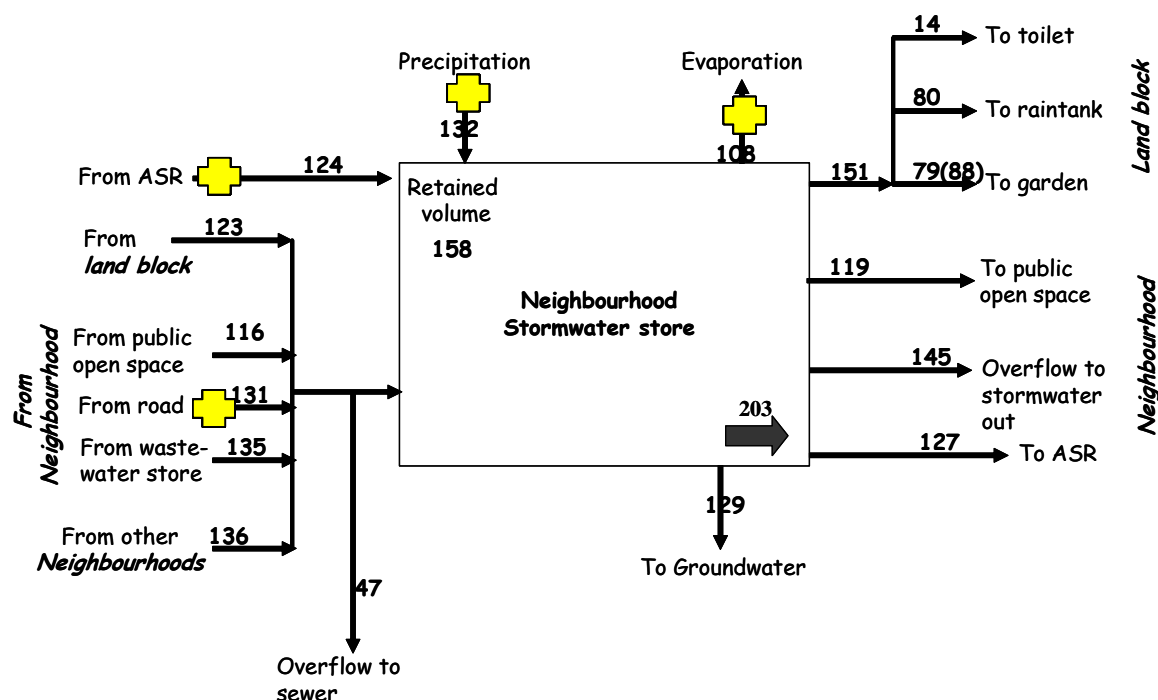


Figure 34 – Neighbourhood stormwater store contaminant inputs and outputs

Neighbourhood Waste water store/treatment

Flows and contaminants to the neighbourhood wastewater store can originate from the following sources;

- Land Blocks,
- Other upstream neighbourhoods, which will occur if wastewater collection from upstream neighbourhoods selected
- Precipitation to the exposed surface of the store

All these contaminants loads are mixed within the store and any load associated with the evaporation stream (specified) is subtracted. The wastewater store sludge is then calculated from the user specified removal efficiency. The appropriate removal efficiency will depend on the contaminant and the type of treatment process being modelled. For example if a simple two stage settlement and aerated biological system is being represented removal of suspended material will be between 40 and 60%. If a higher level of treatment is assumed i.e. membrane bioreactor, then up to 100% of suspended material will be removed. Some suggested values for removal efficiencies of the different wastewater treatment processes are given in Metcalf and Eddy (1991).

Once the sludge calculation is complete and the associated contaminants are removed from the process, the remaining contaminants are either retained within the wastewater store or flow to the land block toilet, raintank or garden, the neighbourhood public open space, groundwater or overflow to stormwater or sewer. The destination of the treated wastewater is user specified. The calculated concentration of these all these streams will be the same.

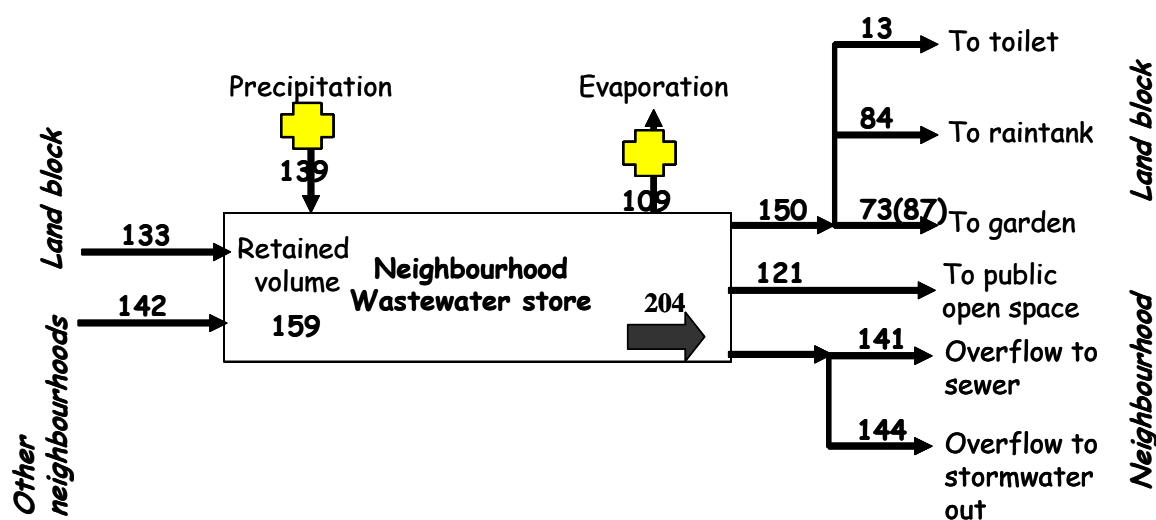


Figure 35 – Neighbourhood wastewater store contaminant inputs and outputs

Study area stormwater store/treatment

Flows and contaminants to the study area stormwater store can originate from the stormwater flows from user specified neighbourhoods. Precipitation to the exposed surface of the store is also an input. The contaminants loads are mixed within the store and any load associated with the evaporation stream (specified) is subtracted. The stormwater store sludge is then calculated from the user specified removal efficiency. The removal efficiency will depend on the contaminant and the type of process being modelled. For example if a simple retention basin is being represented removal of suspended material will be between 40 and 60%. If a higher level of treatment is assumed i.e. microfiltration, then up to 99.9% of suspended material will be removed. Some suggested values for removal efficiencies of the stormwater treatment processes are given in Australian Runoff Quality (2004).

Once the sludge calculation is complete and the contaminants have been removed from the store, the remaining contaminants are either retained within the stormwater store or flow to the land block toilet or garden, the neighbourhood public open space, or overflow to the study area total stormwater output. The destination of the output from the store is specified by the user. The calculated concentration of these output streams is the same.

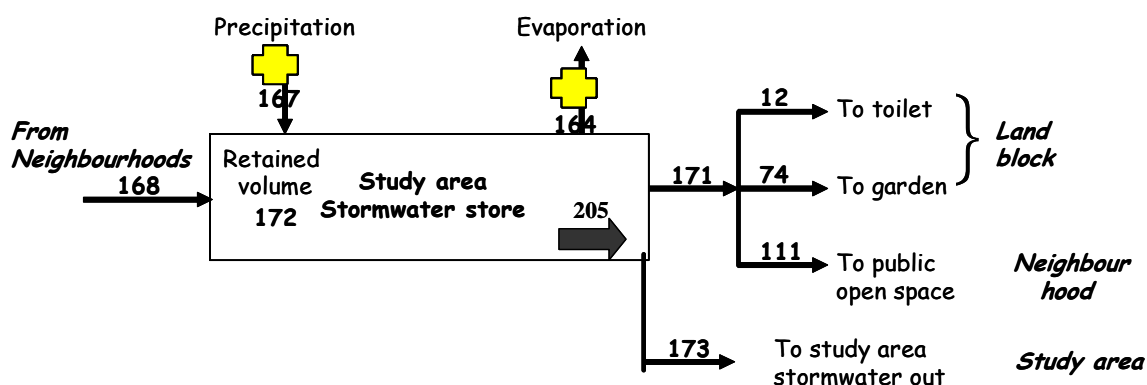


Figure 36 – Study area stormwater store contaminant inputs and outputs

Study area wastewater store/treatment

Flows and contaminants to the study area wastewater store can originate from the wastewater flows from user specified neighbourhoods. Precipitation to the exposed surface of the store is also an input. The contaminants loads are mixed within the store and any load associated with the evaporation stream (specified) is subtracted. The wastewater store sludge is then calculated from the user specified removal efficiency. The removal efficiency will depend on the contaminant and the type of process being modelled. For example if a simple two stage settlement and aerated biological system is being represented, removal of suspended material will be between 40 and 60%. If a higher level of treatment is assumed i.e. membrane bioreactor, then up to 100% of suspended material will be removed. Some suggested values for removal efficiencies of the wastewater treatment processes are given in Metcalf and Eddy (1991).

Once the sludge calculation is complete and the contaminants have been removed from the store, the remaining contaminants are either retained within the wastewater store or flow to the land block toilet or garden, the neighbourhood public open space or overflow to the total study area wastewater output. The destination of the treated wastewater is specified by the user. The calculated concentration of these output streams is the same.

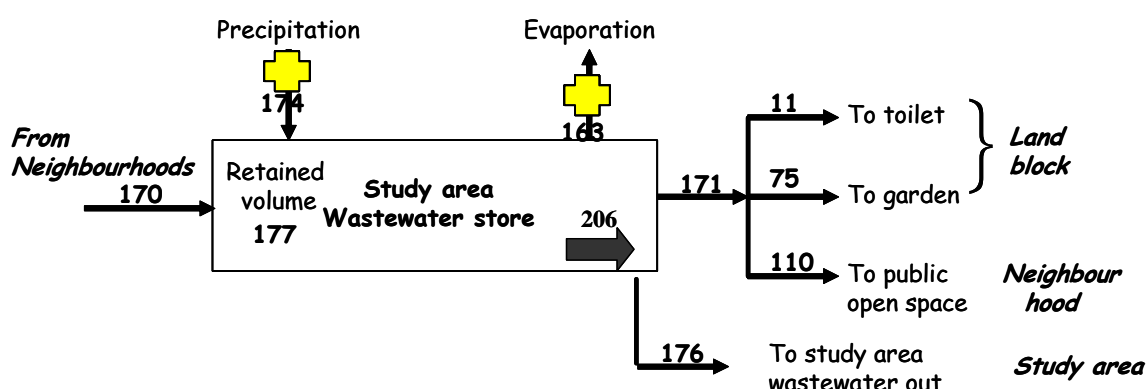


Figure 37 – Study area wastewater store contaminant inputs and outputs

Study area evaporation

The study area total evaporated contaminants is calculated from the sum of all the user specified evaporated contaminants and will have the same concentration as the user specified value, which can be different for different neighbourhoods. The representation of contaminants evaporation in UVQ is the contaminants evaporate from surface stores on all impervious surfaces and from subsurface stores of pervious surfaces. Whilst this is not an accurate representation of the behaviour of evaporated contaminants this simplification was required in order to match water and contaminants flow calculations. Contaminants loads from the land block paved area, garden and roof, the neighbourhood roads, open space and stormwater and wastewater stores, all loads from other neighbourhoods and from the study area stormwater and wastewater stores are summed to provide the total study area evaporation.

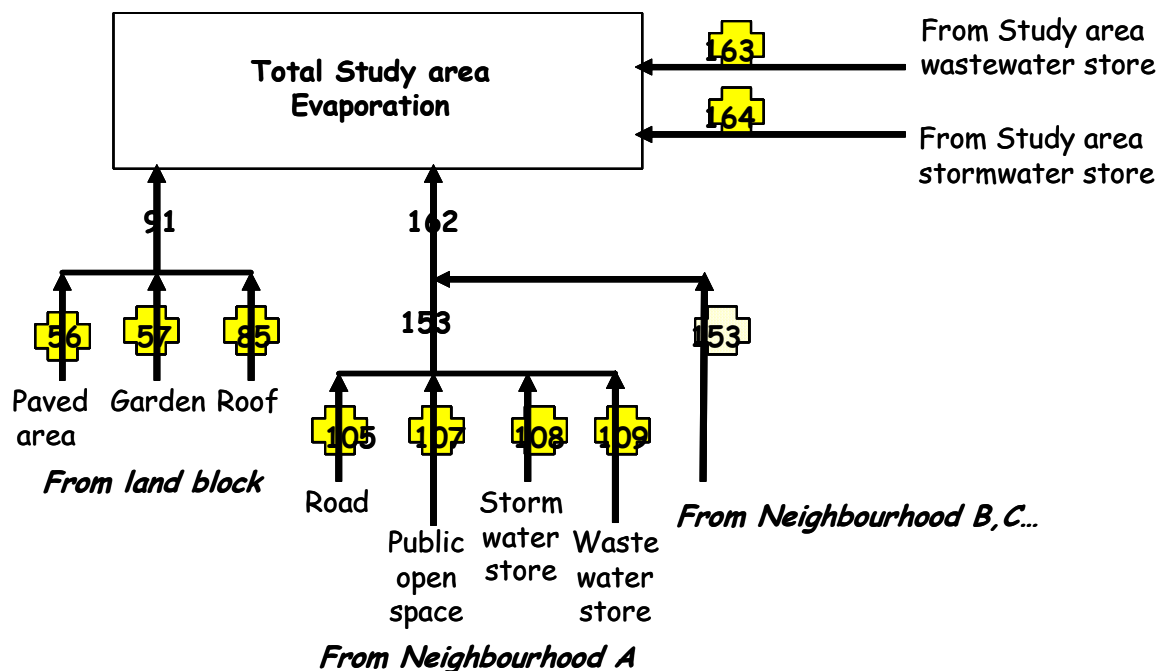


Figure 38 – Total study area evaporation contaminant inputs

The water system variation processes

This section describes the water system variation processes:

- Stormwater store operation
- Wastewater treatment and storage operation
- Aquifer and recovery operation
- Transfer of water between neighbourhoods
- Assessing performance of a reuse scheme

Stormwater store operation

Land block rain tanks, neighbourhood and study area stormwater stores can be represented as simple tanks or reservoirs. The water surface within a stormwater store can be assumed to remain horizontal due to the relatively small size of it. Therefore, the volume held within the store is directly related to the elevation of the free surface. Overflow equals the volume of inflow which exceeds the available storage of the store. All water held within the storage can be assumed to be available for use, i.e. the active storage equals the storage capacity. The operation of the stormwater store can be represented by the water balance equation³:

$$S_t = S_{t-1} + In_{sw} - ff - C_{sw} - O_{sw} - E_p + P$$

where S_t is the stormwater storage volume at the end of the current time step, In_{sw} is the inflow of stormwater runoff, ff is the first flush of stormwater diverted from the inflow, C_{sw} is the volume of stormwater taken from the store for water consumption, O_{sw} is the amount of overflow, E_p is the evaporation from the stormwater store, P is the precipitation entering the stormwater store, Inf is the infiltration from the store to groundwater when the store is acting as an infiltration basin and S_{t-1} is the storage volume at the end of the previous time step. Figure 39 illustrates the structure of this conceptual model of a stormwater store.

Figure 39: Structure of the stormwater store

The storage volume cannot exceed the storage capacity or drop below zero (empty storage) at any time. The volume of water taken from the stormwater store for consumption is dependent on the volume available in the store, once overflow and evaporation have been removed.

Evaporation from an open water surface is assumed to occur at the potential evaporation rate as no transpiration occurs and equals the area of uncovered open water surface multiplied by the potential evaporative demand of the given day. The amount of precipitation falling directly into the surface of the stormwater store also depends on the area of open water surface, if any.

³ The subscript 'sw' in the symbols refers to the fact that these quantities relate to the operation of a stormwater store

The first flush of runoff generated from a small impervious surface such as a roof may contain higher concentrations of pollutants than the rest of the flow; this first flush may or may not be of sufficient quality to be used for the purpose selected (Duncan and Wight, 1991). Stormwater runoff from larger areas, such as an urban catchment, can also display a pattern of initially higher concentrations of contaminants (Cordery, 1977).

Infiltration from a stormwater store only occurs when the two layer soil store is selected. Infiltration is calculated from the area of the store and the infiltration index.

In order to increase the overall quality of the runoff entering the tank an initial quantity of runoff may be diverted from the inflow. Therefore, the option to divert the first flush of flow away from a stormwater store is available.

Wastewater treatment and storage operation

Compared to stormwater runoff (which is intermittent), the discharge of wastewater is constant. Wastewater treatment units usually operate on the basis of inflow displacing water within the plant, creating outflow. It can be assumed, at a daily scale, that there is no lag between inflow and the consequent outflow, hence, a continuous flow of effluent leaves a treatment unit. This effluent flow may either be stored for latter use or disposed of.

Since it is assumed that the wastewater treatment process causes no lag in the flow, only the storage of the wastewater effluent requires modelling. The operation of the wastewater store (Figure 40) can be represented by the water balance equation⁴:

$$W_t = W_{t-1} + In_{ww} - C_{ww} - O_{ww} - E_p + P$$

where W_t is the wastewater storage volume at the end of the current time step and W_{t-1} is the wastewater storage level at the end of the previous time step, In_{ww} is the inflow of wastewater into the store in the current time step, C_{ww} is the volume of wastewater extracted from the store for water consumption in the current time step, O_{ww} is the wastewater overflow volume in the current time step, E_p is the potential evaporation from the wastewater store in the current time step and P is the precipitation entering the wastewater store in the current time step.

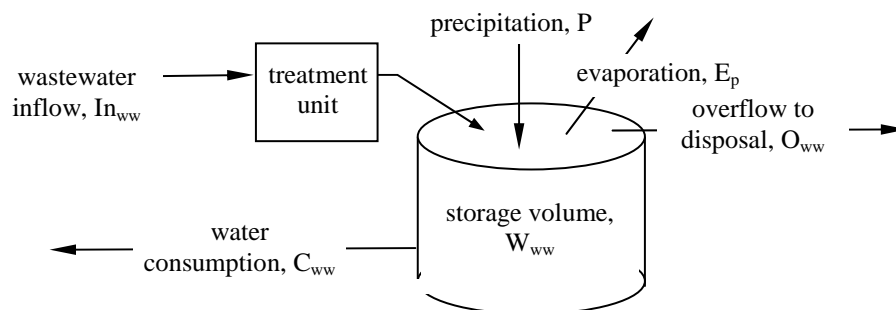


Figure 40 : Structure of the wastewater treatment and storage unit

⁴ The subscript 'ww' in the symbols refers to the fact that these quantities relate to the operation of store associated with a wastewater store.

Aquifer store and recovery operation

Aquifer storage and recovery (ASR) is the process of storage of water in an aquifer for later withdrawal and use. Artificial recharge of an aquifer is the process by which human action is responsible for the transfer of surface water to the groundwater system (Digney and Gillies, 1995). ASR is used to;

- i) increase the yield of an aquifer that is already exploited, or
- ii) take advantage of natural subsurface storage capacity instead of relying on surface storage.

In UVQ, the aquifer is assumed to have a fixed storage capacity, with all recharge water retrievable at a later time. An aquifer has a finite maximum rate at which it can accept water through an injection well (Pavelic et al., 1992); this rate is a function of the hydraulic gradient, aquifer permeability, and length and type of screen in the injection well (Oaksford, 1985). The maximum rate of retrieval of the injected water, through pumping, is also finite.

The use of a temporary surface store would lessen the problem of limits on the rate at which water can be transferred into or out of the aquifer.

The operation of the aquifer storage and recovery system can be represented by the following water balance equations, with the first equation relating to the surface section of the system and the second relating to the sub-surface section of the system (as shown in Figure 41):

$$AS_t = AS_{t-1} + In_a - I_j + R - C_a - O_a - E + P$$

$$A_t = A_{t-1} + I_j - R$$

where AS_t is the surface storage volume at the end of the current time step, A_t is the aquifer storage volume at the end of the current time step, In_a is the supply of water for recharge in the current time step, C_a is the volume of water taken from the surface store for water consumption in the current time step, O_a is the surface store overflow in the current time step, I_j is the volume of water injected into the aquifer in the current time step, R is the volume of water recovered from the aquifer in the current time step, E is the evaporation from the surface store in the current time step, P is the precipitation entering the surface store in the current time step, AS_{t-1} is the surface storage volume at the end of the previous time step, and A_{t-1} is the aquifer storage volume at the end of the previous time step.

The recharge of the aquifer is limited by the maximum rate of recharge and the availability of the aquifer storage, while the recovery of water from the aquifer is limited by the maximum rate of recovery and the availability of water in the aquifer. Since the aquifer is an underground store, there is no loss due to evaporation or storage gain through incident precipitation. There is also assumed to be no deep seepage from the aquifer.

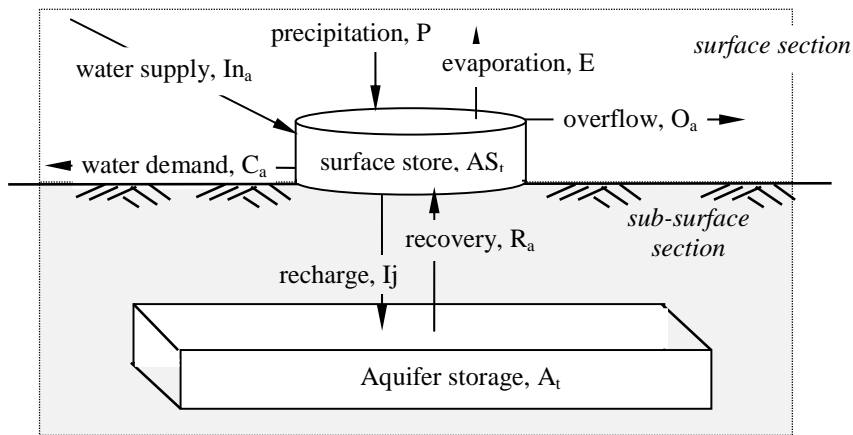


Figure 41 : Aquifer storage and recovery system structure

Transfer of water between neighbourhoods

Stormwater and wastewater can be transferred between neighbourhoods for reuse. For example, when water from Neighbourhood 2 is used in Neighbourhood 1 this is considered a transfer of water out of Neighbourhood 2 and into Neighbourhood 1. It is not a flow due to stormwater or wastewater drainage, it is a flow due to the reuse of stormwater or wastewater.

A positive value for the “Transfer of water” indicates the amount of water sourced from other Neighbourhoods in the results screen water balance table for reuse (see Results). Conversely, negative value for the “Transfer of water” indicates the amount of water sourced by other Neighbourhoods for reuse. A positive value indicates a net transfer into the neighbourhood and a negative value indicates a net transfer out of the neighbourhood.

Assessing performance of a reuse scheme

UVQ uses several measures of performance; number of event failures, deficit and annual volumetric reliability.

In the case of event failure, an inability to provide anything but all of the demand in a time step is considered a failure, reducing the storage’s overall reliability. Performance is reported in the number of days of event failure (see Results). At study area scale the event failure reported in output files is the **sum** of all the neighbourhoods.

The deficit of a store is the shortfall of water in kL when compared to demand.

Annual volumetric reliability, R_v , as a percentage, is defined as:

$$R_e = 100 * (S_v / D_v)$$

where S_v is the total volume supplied and D_v is the volume demanded in the simulation period. Volumetric reliability measure s the severity of failure to meet the supply of water demanded.

Tutorial

The tutorials contained in this section of the user manual describe the simulation process and show you how to use UVQ to represent a conventional water servicing approach and investigate the use of alternative water servicing strategies. The tutorial uses a scenario involving a proposed residential, commercial and industrial development project to guide you step-by-step through the simulation process.

Because of the amount of data you collate throughout the tutorial, you may find it useful to use worksheets provided (see section Worksheets) to record the simulation parameters as you progress through the tutorial. The information required for each worksheet is arranged to match the format of the screens into which you will enter the data within UVQ.

The simulation process

UVQ is a tool that simulates conventional and innovative water systems within an urban area. The first step is to simulate the conventional water system through collection of data and calibration. Once the model is calibrated for the conventional system, the configuration of the integrated water system can be manipulated to ascertain the consequences of altering the system on a number of factors; the amount of water and contaminants imported into an urban area via the reticulation system and other sources, the amount of water and contaminants exported out in the form of stormwater and wastewater and the amount of water and contaminants residing in the system.

Data input – Conventional servicing

Metropolis City is the fastest-growing city in the nation. Because they have reached the limit of the water resources and have significant degradation of the region's waterways due to the stormwater and wastewater discharges, the Metropolis City Council have implemented a sustainable water management policy. This policy requires that all new suburban development projects implement an integrated water system (see section *Integrated water management*) with a focus on sustainability principles.

The Eco-Suburban Development Company has applied to the city to develop 143 hectares of an area known as the Heatherwood into a new suburb. This area will contain three distinctive usage zones; a 57.46 hectare residential zone, a 5.74 hectare commercial zone and a 79.8 hectare industrial zone.

Before Metropolis City approves the project, Eco-Suburban Development Company must supply the City with an impact study that outlines how their proposed integrated water system minimizes the impact of Heatherwood development project on the existing water system. The impact study must outline how they will:

- minimize imported water supplied to the site
- minimize amount of wastewater and the contaminant loads flowing from the study site into the conventional central wastewater system
- ensure stormwater and the contaminant loads flowing from the study area into the adjacent waterway are maintained at predevelopment levels

How to profile an urban area

Before you can begin your simulation, you must profile the urban area and its current water system. UVQ simulates an urban area based on configuration parameters you enter relating to the surface area characteristics, the water usage rates, the wastewater characteristics and the stormwater characteristics within the urban area. This section shows you how to define the urban area in a manner that allows UVQ to simulate the water cycle.

To simulate the urban area, UVQ requires that you define the:

- spatial dimensions of the urban area it is simulating
- surface area characteristics of each spatial area
- water usage rates within each spatial area
- wastewater characteristics of each spatial area
- stormwater characteristics of each spatial area
- contaminant characteristics of each spatial area

Defining the spatial dimensions

This section shows you how to define the spatial dimensions of the urban area in a manner that allows UVQ to simulate it accurately. UVQ uses three spatial scales to represent the urban area; the land block, the neighbourhood and the study area. UVQ uses these scales to capture the surface area configuration, water usage rate and wastewater contaminant inputs within the urban area to estimate the quality and quantity of the stormwater and wastewater produced.

Defining your study area dimensions

The study area is the largest spatial scale used within UVQ is the total size of the urban area you are simulating.

A study area represents an urban area containing a number of neighbourhoods and can have mixture of land uses such as residential, industrial, commercial and institutional. These neighbourhoods may relate to the suburbs in the study area or areas of a single land use. A common example of a study area is a suburb which contains residential, commercial and industrial neighbourhoods. Figure 42 illustrates a typical study area.



Figure 42 : An example study area.

To model a study area, you must identify the number of neighbourhoods that make up the study area and the configuration characteristics of each neighbourhood within the study area.

Modelling a study area allows you to investigate the cumulative effects of different water management strategies within the neighbourhoods within a study area or to explore the feasibility of having different water systems within neighbourhoods that have different characteristics. The drainage network linking these neighbourhoods, in terms of the flow of stormwater and wastewater can be stated and the way in which stormwater and wastewater flow through the study area, from neighbourhood to neighbourhood can be represented.

The study area of the Heatherwood development site is 143 hectares.

If you are using the worksheets, on the Project Information worksheet, enter the total size of the Heatherwood development project study area (143 ha) and define the description as “The Heatherwood Project”.

Defining your neighbourhood dimensions

UVQ requires that you identify zones within your study area that have similar:

- land use
- pervious and impervious surface area configurations
- indoor and outdoor water usage rates.

When setting up the neighbourhoods in UVQ remember that flows can only be directed from a lower number neighbourhood to a higher number. Thus it is useful to have stormwater and wastewater drainage systems so that upstream and downstream zones can be represented accordingly. Once these zones have been identified they can be split further into smaller neighbourhoods representing the different housing types within these zones.

The purpose for which a neighbourhood is used may impact upon the quantity and the quality of the stormwater and wastewater it produces. For example, a neighbourhood used

for commercial purposes may produce less wastewater with fewer contaminants within it than an industrial area. Identifying quality and quantity requirements for a range of water uses (end uses) and the quantity and quality of wastewater and stormwater produced within the different neighbourhoods within your study area allows you to determine where and how you can modify the demand for water supply or reduce contaminant loads for example. Modifications include water efficient practices or the reuse of wastewater and stormwater.

A Neighbourhood represents a number of land blocks, roads and public open space which form a local area or suburb. A common example of a neighbourhood is a group of residential land blocks, with a shared local park and roads. Alternatively, the land blocks in the neighbourhood could be used for commercial, industrial or institutional purposes.

To simplify the modelling process, a neighbourhood is made up of numerous groups of land blocks that are used for the same purpose such as residential, industrial or commercial and share facilities such as public open space and local access loads.

The configuration of a neighbourhood components may change based on how land blocks within a neighbourhood are used. A neighbourhood that simulates an industrial area may only contain industrial land blocks and roads (Figure 43). While a neighbourhood that simulates an area used for institutional purposes such as large university campuses may contain the institutional land blocks, a number of open spaces and roads. Alternatively, a neighbourhood may contain solely open space or solely roads or solely land blocks.

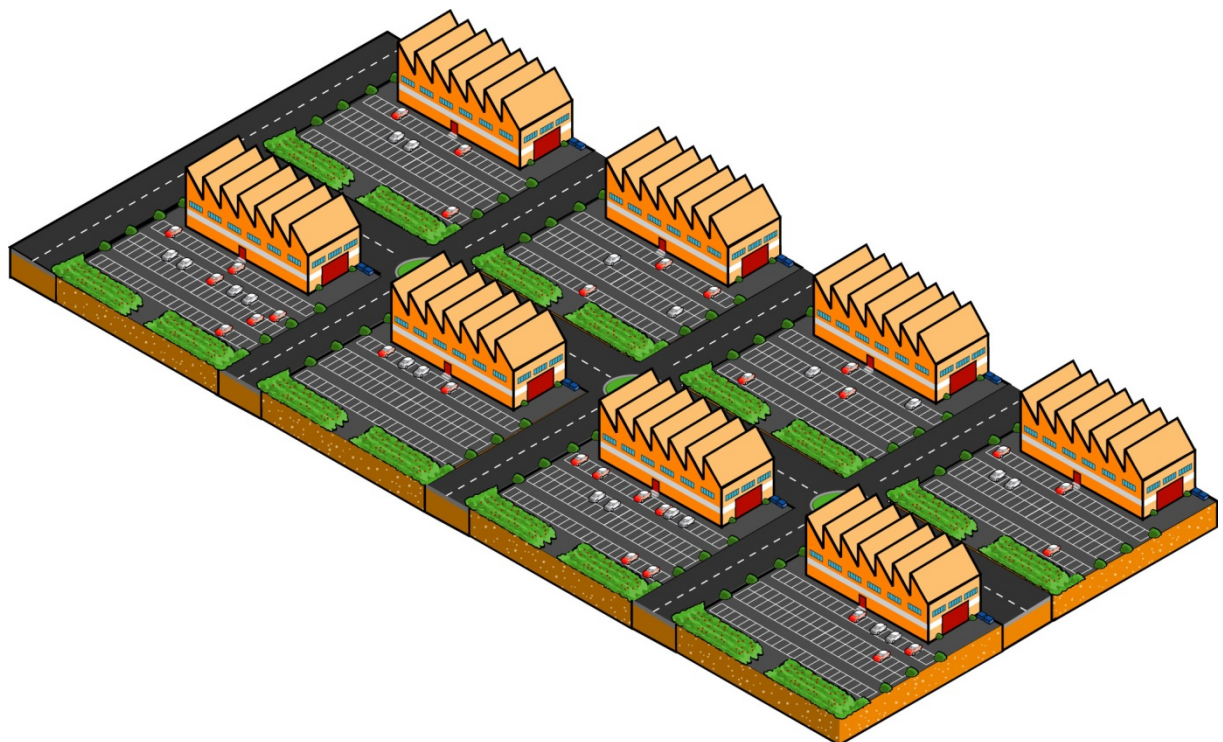


Figure 43 : An example industrial neighbourhood.

To model the neighbourhood, you must define the road and public open space areas as well as the land block characteristics contained in the neighbourhood.

The proposed Heatherwood development has three neighbourhoods, a residential, an industrial and a commercial neighbourhood, with different pervious and impervious surface area configurations, water usage rates, wastewater characteristics and water pollutant characteristics. The area within each of these neighbourhoods has similar surface configurations and imported water usage statistics and water pollutant characteristics. Figure 44 illustrates the neighbourhoods within the proposed Heatherwood study area.



Figure 44 : Heatherwood study area neighbourhoods

UVQ requires that you specify the total area of each of your neighbourhoods. The developers of the Heatherwood site are proposing a residential neighbourhood of 57.46 hectares, a commercial neighbourhood of 5.74 hectares and an industrial neighbourhood of 79.8 hectares.

If you are using the worksheets,

- On the Project Information worksheet, enter the number of neighbourhoods
- On the Physical Characteristics of Land Blocks and Neighbourhoods worksheet, enter the total area of each neighbourhood in the Total area field in the Neighbourhood frame section of the worksheet. Define the residential neighbourhood as “Neighbourhood 1” the commercial neighbourhood as “Neighbourhood 2” and the industrial neighbourhood as “Neighbourhood 3”.

Defining your land block dimensions

The land block is the smallest management scale possible for water supply, stormwater runoff, and wastewater disposal used within UVQ and it is a useful fundamental spatial scale for this type of modelling. It is used to represent a single property within a neighbourhood that may contain building(s), paved areas and garden or open space areas. A common example of a land block is a residential property that contains a house, a driveway and a garden (Figure 45). Land blocks may also represent commercial, industrial or institutional sites such as a shop, factory or a school.

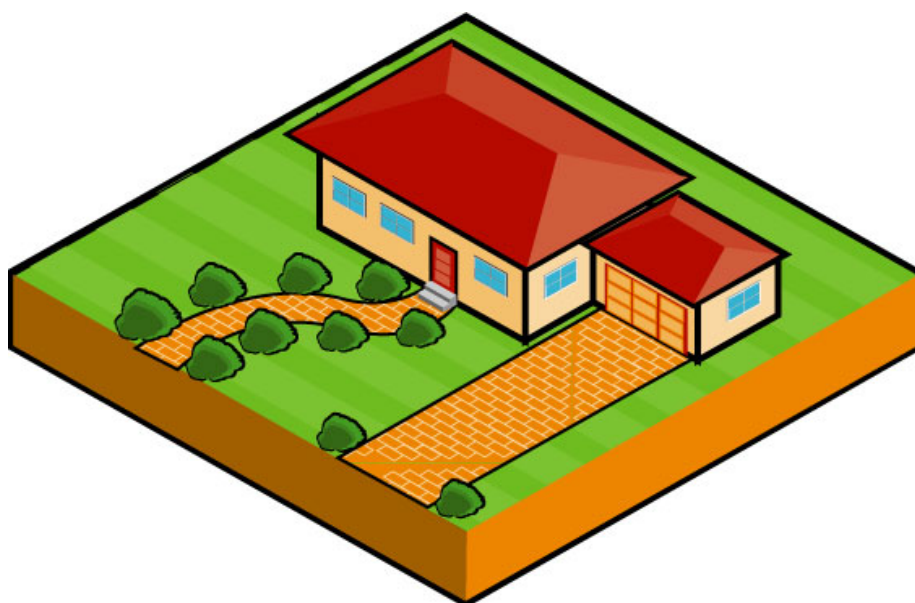


Figure 45 : Residential land block.

To model the land block, you must specify the roof area, the pervious surface areas (garden, open areas) and the impervious surface areas (roof, road, paving).

Modelling the land block allows you to investigate the effect of the land block characteristics such as size, occupancy, water demands and the cumulative effect of individuals' water usage habits on a study area. Varying land use and garden watering patterns are also accounted for at the land block scale within a neighbourhood.

UVQ treats land blocks within a neighbourhood homogeneously. You must identify the number of land blocks within each of your neighbourhoods and calculate their average size.

For the Heatherwood project the number of residential land blocks in Neighbourhood 1 is 711. In the commercial neighbourhood the commercial buildings will be modelled as one, and in the industrial neighbourhood there are 75 identical industrial plots. Table 1 summarizes this information and provides the data required for the average land block size within each neighbourhood.

Table 1 : Number and area of Heatherwood land blocks.

Data Requirement	Neighbourhood 1 – residential	Neighbourhood 2– commercial	Neighbourhood 3– industrial
Number of land blocks	711	1	75
Block Area m ² (average size)	620	12000	9300

If you are using the worksheets, on the Physical Characteristics Of Land Blocks and Neighbourhoods worksheet, enter the number of land blocks within each neighbourhood in

the Number of Land Blocks field and the average land block size in the Block Area field in the Land Block frame section.

Defining the surface area coverage

Because different surface types impact upon the quality and the quantity of water in the urban water cycle UVQ requires detailed information about the impervious and pervious surface coverage within your study area. This section shows you how to define the surface area coverage within your study area in the manner required by UVQ.

Defining the impervious and pervious surface dimensions

To simulate the impact of the impervious and pervious surfaces on the quantity of stormwater and wastewater systems, UVQ requires that you specify the dimensions of pervious and impervious surface at the neighbourhood scale and the land block scale.

Pervious areas comprise of open space within neighbourhoods and gardens within land blocks.

Impervious surfaces areas are the surfaces within the study area that water does not infiltrate to the soil. The impervious surfaces UVQ regards as having a significant effect on the amount of water that flows into the stormwater system are the roads within neighbourhood and the roofs and paved areas within a land block.

Defining the land block surface dimensions

Because UVQ treats the land blocks within neighbourhoods homogeneously, you must calculate the average size of the impervious and pervious areas within the land blocks in each neighbourhood. UVQ requires the average dimensions of the roof, paving and garden surface areas within the land block. How the land block is used determines the amount of roof, paving and garden surface areas within the land block. For example, a residential property may have more garden area than an industrial property.

Table 2 shows the average dimensions of the pervious and impervious surfaces within the land blocks in Heatherwood Development Project.

Table 2 : Heatherwood land block pervious and impervious surface dimensions

Data Requirement	Neighbourhood 1 – residential	Neighbourhood 2– commercial	Neighbourhood 3– industrial
Garden area (m ²)	370	0	1300
Roof area (m ²)	200	4000	2300
Paved area (m ²)	50	8000	5700

If you are using a worksheet, on the Physical characteristics of land blocks and neighbourhoods worksheet, enter the garden dimensions into the Garden Area field, the roof dimensions into the Roof Area field and the Paved dimensions into the Pave Area field into the Land Block frame section.

At this site, spoon drains are not being used, so the Proportion Roof Runoff to Spoon drain field can either be left blank or have a zero entered into it

Defining the neighbourhood surface dimensions

The neighbourhood spatial scale represents a number of land blocks, roads and public open space. Figure 46 illustrates the proposed configuration of the residential neighbourhood within the Heatherwood Project.

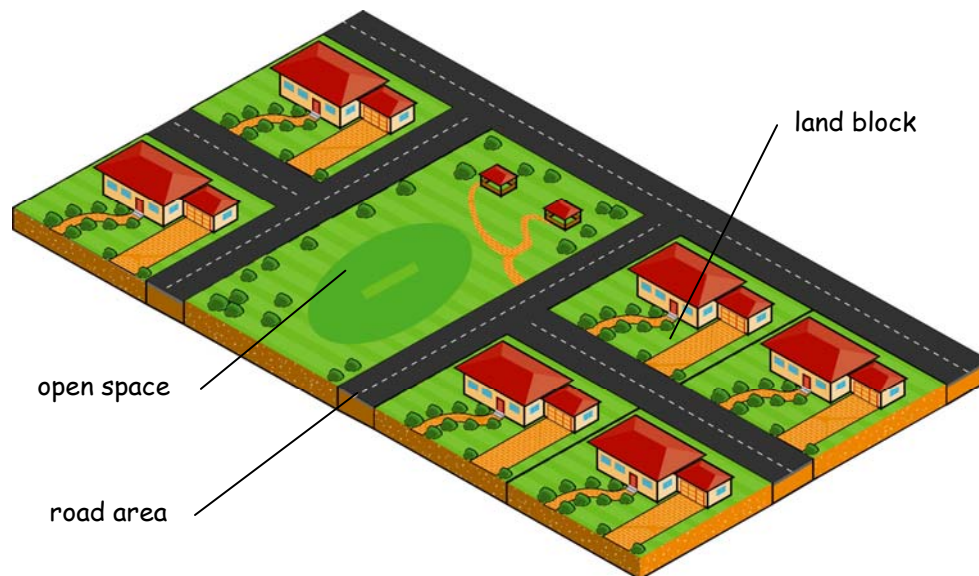


Figure 46 : Heatherwood project residential neighbourhood surface configuration

The next level of detail required is to specify the number of hectares within a neighbourhood that contain roads (or other impervious surfaces) and the number of hectares that contain pervious surfaces such as parks or bush land. UVQ assumes road areas are 100% impervious and impervious footpaths and guttering should be included as part of the road area. Table 3 shows the dimensions of the road areas and open spaces within Heatherwood Development Project.

Table 3 : Heatherwood neighbourhood surface area dimensions

Data Requirement	Neighbourhood 1 – residential	Neighbourhood 2– commercial	Neighbourhood 3– industrial
Road area (ha)	11.378	1.14	10.05
Open space area (ha)	2	3.4	0

If you are using the worksheets, on the Physical Characteristics Of Land Blocks And Neighbourhoods worksheet, enter the dimensions of the road area into the Road Area field and the open space dimensions into the Open Space Area field within the Neighbourhood frame section.

Defining the water usage rates

In a conventional water supply system, all indoor uses and outdoor irrigation uses would be supplied by imported water. Leakage will also occur from the water supply reticulation pipes. Therefore, the total amount of water imported to the study site is the sum of indoor water usage, outdoor water usage and pipe leakage.

How you use water indoors in a study area impacts upon the quantity and quantity of the subsequent wastewater generated.

To simulate the usage of water, UVQ requires that you specify the:

- amount of water used indoors in the kitchen, bathroom and laundry and toilet within each land block
- percentage of water that leaks from broken and cracked pipes within each neighbourhood
- percentage area of gardens and open space which is irrigated in each neighbourhood
- estimate of the trigger to irrigate parameter for gardens and open space.

Defining the indoor water usage characteristics

Specifying average occupancy and indoor water usages rates

To calculate the amount of water used in a neighbourhood for indoor water use, UVQ requires that you specify the average number of people occupying each land block within each neighbourhood and the average amount of water used per person in the bathroom, toilet, laundry and kitchen. Table 4 shows the indoor water usage statistics for the Heatherwood project.

Note the **Template** function can be used for parameters which are common to all neighbourhoods. To save time inputting data it is worth entering all common data and then using the **Template** function. The **Template** function may also be used for changing the order of neighbourhoods within the study area if required after inputting all parameters.

Table 4 : Heatherwood indoor water usage.

Data Requirement	Neighbourhood 1 – residential	Neighbourhood 2– commercial	Neighbourhood 3– industrial
Average occupancy	3	36	30
Kitchen L/c/d	13.2	13.2	7
Bathroom L/c/d	56.8	56.8	30
Toilet L/c/d	21	21	299 (represents all non-potable industrial demand)
Laundry L/c/d	44.8	44.8	24

If you are using the worksheets, on the Physical Characteristics... worksheet, specify average occupancy and the volume of water for each of the indoor areas in the equivalent fields on the worksheet.

Contaminants added when water is used indoors

Contaminants are added to water during its usage indoors, creating wastewater. In the Heatherwood Development Project the contaminants, Nitrogen (N), Phosphorus (P) and Suspended Solids (SS) have been chosen to be simulated as they are important in the performance of wastewater treatment plant and in the health of surface waters.

Table 5 : Heatherwood water usage contaminant values.

Field	Neighbourhood 1 – Residential	Neighbourhood 2 - Commercial	Neighbourhood 3 - Industrial
Indoor Usage & Contaminants frame – Physical Characteristics... screen			
Kitchen Contaminants (mg/c/d)	N = 238 P = 42 SS = 3990	N = 238 P = 42 SS = 3990	N = 238 P = 42 SS = 3990
Bathroom Contaminants (mg/c/d)	N = 462 P = 22 SS = 8303	N = 462 P = 22 SS = 8303	N = 462 P = 22 SS = 8303
Toilet Contaminants (mg/c/d)	N = 13709 P = 1568 SS = 36240	N = 13709 P = 1568 SS = 36240	N = 13709 P = 1568 SS = 36240
Laundry Contaminants (mg/c/d)	N = 327 P = 152 SS = 4858	N = 327 P = 152 SS = 4858	N = 327 P = 152 SS = 4858

These contaminants were selected because the primary objectives of the study are to reduce wastewater and stormwater flows and contaminants from the site. Table 5 outlines the contaminants added to the water when used in the kitchen, bathroom, laundry and toilet.

If you are using the worksheets, on the Physical Characteristics... worksheet, specify the water usage contaminant loads in the equivalent fields on the worksheet. In the Project Information... worksheet, specify that N, P and SS are the contaminants analysed in this study.

Defining the reticulated water supply leakage parameters

The physical condition of the reticulated water system infrastructure impacts upon the quantity of water leaking out of the water supply pipes. Water from cracked and broken water supply pipes flows into the groundwater store and ultimately into the stormwater system. A figure for the percentage of water leaking into the groundwater store from the reticulated water infrastructure is required (it can be set to 0%). Estimates for this value can be made or local water supply organisations may provide a value.

Table 6 specifies the imported supply leakage percentage for each neighbourhood within the Heatherwood project as advised by the Metropolis City Water Board.

Table 6 : Heatherwood water system leakage parameters.

Data Requirement	Neighbourhood 1 – residential	Neighbourhood 2– commercial	Neighbourhood 3– industrial
Imported water leakage (%)	5	5	5

If you are using the worksheets, on the Physical Characteristics... worksheet, enter the imported water leakage percentage for each neighbourhood in the Imported Supply Leakage field.

Setting the irrigation parameters

Irrigation is the amount of water provided to supplement precipitation to maintain the desired vegetation condition or growth rate.

UVQ requires that you specify the percentage of garden and open space within each neighbourhood which is irrigated. For UVQ to calculate the volume of irrigation required to maintain growth, you must also estimate a trigger to irrigate ratio. The trigger to irrigate represents the level of soil wetness that the irrigator wants to maintain. If the soil water storage level drops below this trigger level then irrigation is requested from the various sources available to it.

Table 7 and Table 8 show the irrigation values and trigger to irrigate values estimated for the Heatherwood development project.

Table 7 : Heatherwood percentage irrigated area values.

Data Requirement	Neighbourhood 1 – residential	Neighbourhood 2– commercial	Neighbourhood 3– industrial
Percentage of garden irrigated (%)	70	30	0
Percentage of open space irrigated (%)	100	100	0

Table 8 : Estimated Heatherwood irrigation values.

Data Requirement	Neighbourhood 1 – residential	Neighbourhood 2– commercial	Neighbourhood 3– industrial
Garden trigger to irrigate (ratio)	0.5	0.5	0.5
Open space trigger to irrigate (ratio)	0.5	0.5	0

If you are using the worksheets, on the Physical Characteristics... worksheet, specify the percentage of the open space requiring irrigation in the Neighbourhood frame and the garden area requiring irrigation in the Land Block frame.

On the Calibration variables worksheet, specify the garden trigger to irrigate ratios in the Irrigation frame.

Defining the wastewater characteristics

The quantity and quality of wastewater generated within an area, and ultimately the amount of water available for utilisation, is affected by the physical capacity and condition of the wastewater system. To simulate how much water is available for utilisation and where within the wastewater system water may be used, UVQ requires that you define the:

- configuration of the wastewater system within a study area
- amount of surface runoff flowing into the wastewater system due to stormwater inflow and infiltration
- wastewater system exfiltration parameters
 - capacity of the wastewater system.

Defining the configuration of the wastewater system

To determine where and how much wastewater you may reclaim, UVQ requires that you define the configuration of the wastewater system. You do this by arranging the flow pathways in the Water Flow screen. As a default, each neighbourhood's wastewater flows straight to the Study Area Output. You can direct the wastewater to any neighbourhood which has a higher neighbourhood number or the Study Area Output.

Within the Heatherwood development project, the wastewater from the residential and commercial neighbourhoods flows through separate pipes into the industrial neighbourhood. Figure 47 illustrates this process.

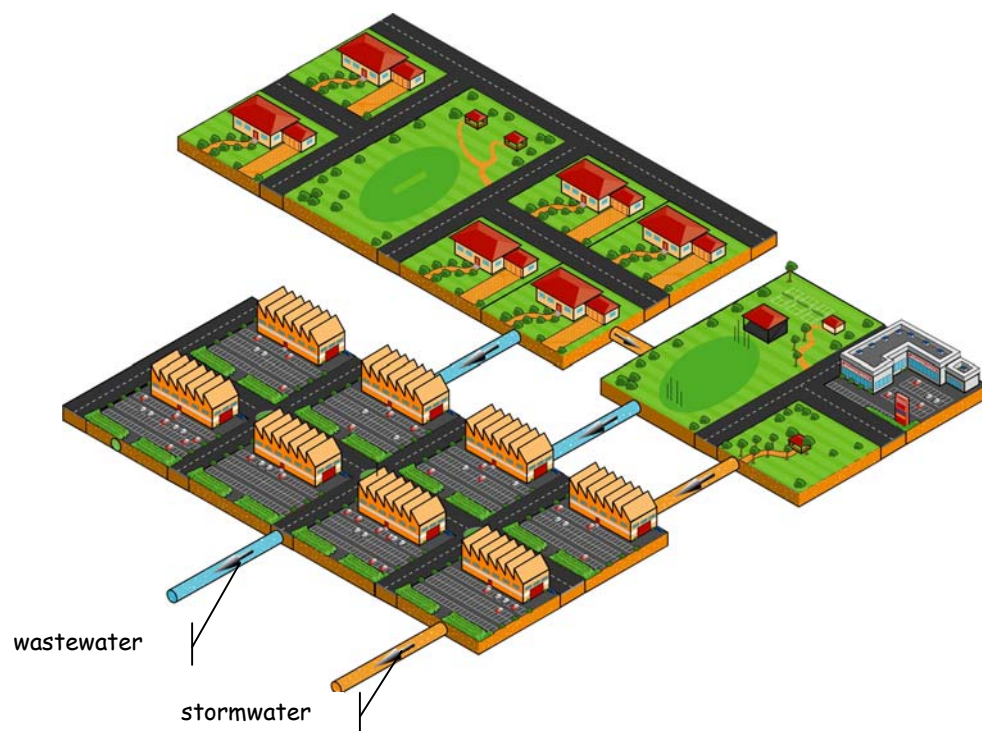


Figure 47 : The Heatherwood development project stormwater and wastewater system configuration.

Table 9 specifies the configuration of the Heatherwood wastewater and stormwater systems using the neighbourhood identification numbers.

Table 9 : Neighbourhood wastewater configuration identifiers

Data Requirement	Neighbourhood 1 – residential	Neighbourhood 2– commercial	Neighbourhood 3– industrial
Wastewater from neighbourhood goes to	3 (industrial)	3 (industrial)	0 (study area outflow)
Stormwater from neighbourhood goes to	0 (study area outflow)	0 (study area outflow)	0 (study area outflow)

Note: The stormwater system configuration may be defined in the same way. However, within this tutorial the stormwater from all neighbourhoods is set to 0, flowing to the Study Area Output.

If you are using the worksheets, on the Water Flow... worksheet, enter the neighbourhood to which the wastewater flows for each neighbourhood within the study area.

Defining the wastewater system exfiltration and inflow/infiltration parameters

The physical condition of the wastewater infrastructure impacts upon the quantity of the wastewater and thus the overall quality of water flows from the study area. Water from cracked and broken pipes within the wastewater infrastructure enables water to flow into (infiltration) and out of (exfiltration) the wastewater system. To determine the impact these processes have on the movement of water and contaminants through the study area, UVQ requires that you specify/estimate the:

- wastewater exfiltration ratio
- wastewater infiltration parameters
- surface runoff as inflow percentage
- dry weather overflow rate
- wastewater system capacity

Specifying the wastewater exfiltration ratio

Wastewater exfiltration is the ratio of water leaking from the wastewater system into the groundwater store through cracked and broken pipes. Wastewater exfiltration impacts the quality and quantity of water within the groundwater and ultimately the stormwater.

The estimated wastewater exfiltration ratio for the wastewater system within each neighbourhood within the Heatherwood Development Project is 0.03.

If you are using the worksheets, on the Physical Characteristics... worksheet, enter the wastewater exfiltration ratio for each neighbourhood.

Estimating wastewater infiltration parameters

Wastewater infiltration is the water that flows into the wastewater system from the surrounding soil and pipe bedding media following rainfall-runoff events. To calculate infiltration, UVQ requires that you provide an initial estimate of the infiltration index ratio and the infiltration store recession constant ratio for each neighbourhood within a study area.

The infiltration index is the ratio of water that flows from the soil stores into the temporary infiltration store due to the excess in soil storage capacity. The infiltration store recession constant regulates the rate at which water flows into the wastewater pipes from the temporary infiltration store.

Table 10 gives the initial estimates of the infiltration parameters for the Heatherwood Development Project.

Table 10 : Estimated Heatherwood infiltration parameters

Data Requirement	Neighbourhood 1 – residential	Neighbourhood 2– commercial	Neighbourhood 3– industrial
Infiltration Index (ratio)	0.05	0	0.05
Infiltration Store Recession Constant (ratio)	0.1	0	0.1

If you are using the worksheets, on the Calibration Variables worksheet, enter the infiltration parameters for each neighbourhood.

Estimating the surface runoff as inflow percentage

The surface runoff as inflow is the percentage of the surface runoff generated in the neighbourhood which flows into the wastewater pipe system rather than the stormwater system, due to possible illegal connections. The surface runoff as inflow percentage for each neighbourhood within the Heatherwood Development Project is estimated to be 3 percent.

If you are modelling a combined sewer system where stormwater and wastewater flow through the same pipes this value needs to be set to 100%.

If you are using the worksheets, on the Calibration Variables worksheet, enter the surface runoff as inflow for each neighbourhood in the wastewater frame.

Estimating the dry weather overflow rate

The dry weather overflow rate is the percentage of wastewater that overflows from the wastewater system into the stormwater system due to pipe choking or blockage. This type of overflow can occur on a daily basis.

As the Heatherwood Development Project is a new build site the dry weather overflow rate for each neighbourhood within the study area wastewater system is estimated to be 0.

If you are using the worksheets, on the Calibration Variables worksheet, enter the dry weather overflow rate for each neighbourhood in the wastewater frame.

Estimating the Wastewater System Capacity

The Wastewater System Capacity (formerly labelled 'wet weather overflow trigger') represents the maximum amount of wastewater the neighbourhood wastewater system can convey each day. All wastewater flowing into the wastewater system in excess of this capacity then becomes overflow and spills into the stormwater system. You can either leave this field blank or estimate a capacity for each neighbourhood within the study area. If you leave the field blank, then the wastewater system is assumed to have an infinite capacity, so overflow does not occur.

All of the wastewater system in the Heatherwood Development Project is assumed to have infinite capacity so the Wastewater System Capacity is left blank or disabled for all neighbourhoods.

Defining the stormwater characteristics

Because different surface and baseflow characteristics impact upon the quality and the quantity of the water that flows into the stormwater and wastewater systems and the amount of water required for irrigation, UVQ requires information about the impervious and pervious surfaces and the baseflow response of the groundwater store within your study area. This section shows you how to define the surface characteristics within your study area in the manner required by UVQ.

To simulate the surface areas accurately, UVQ requires information about the:

- pervious surface store characteristics
- impervious surface store characteristics
- baseflow characteristics.

Estimating pervious surface store characteristics

For UVQ to simulate the soil stores accurately, you must specify which soil store type which will best represent the soil stores within your study area and estimate the capacity of these soil stores to hold water. If you are unsure which soil store type is most appropriate for your site, then select one of the two available and during model calibration you can investigate which enables you to fit the observed stormwater flows more closely.

It is estimated that the Heatherwood Development site has a partial area soil store type with a capacity of 150 mm in soil store 1 and 300 mm in soil store 2, and that soil store 1 covers 15 percent of the gardens and open space. These values are assumed to be the same for each neighbourhood.

If you are using the worksheets, on the Project Information worksheet, specify the Soil Store Type as Partial Area. On the Calibration Variables worksheet, enter the percentage area of soil store 1 in the Percentage Area of Soil Store 1 field, the soil store capacity for soil store 1 and 2 in the Capacity of Soil Store 1 and Capacity of Soil Store 2 fields in the Stormwater frame section of the worksheet. *Remember*, these values are the same for each neighbourhood.

Estimating the impervious surface store characteristics

The impervious surface store characteristics that UVQ requires to calculate the volume of surface runoff are the:

- Maximum initial loss
- Effective impervious surfaces area.

UVQ uses the area maximum initial loss and the effective surface area parameters to calculate the effective impervious surface runoff and the non-effective impervious surface runoff when simulating the main stormwater processes.

In UVQ, each impervious surface is modelled as a single storage runoff saturation excess process. The water retained in each store represents the initial losses due to interception and depression storage. Figure 48 illustrates this process.

Effective impervious surface runoff is the amount of water from impervious surfaces (road, paved and roof) that contributes to the total stormwater flow. Runoff from impervious surfaces which are not directly connected to the stormwater drainage system and drain onto adjacent pervious surfaces is known as non-effective surface runoff.

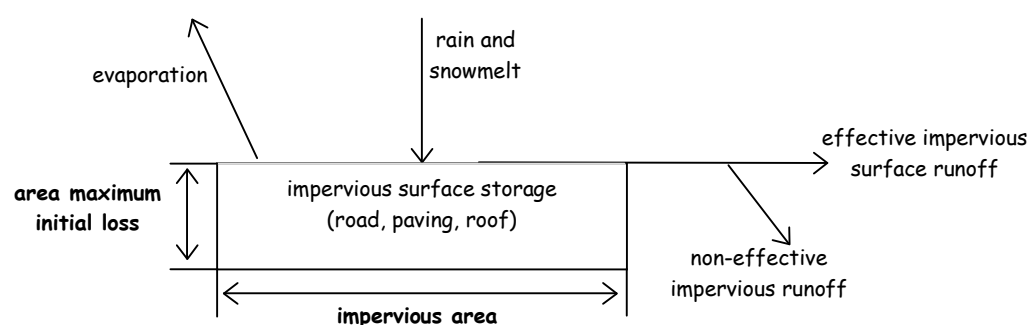


Figure 48 : The impervious surface runoff process.

Estimating maximum initial loss

The maximum initial loss is how many millimetres of water an impervious surface can store before runoff occurs. Table 11 shows the initial estimates of impervious surfaces maximum initial loss for the Heatherwood development project.

Table 11 : Estimated Heatherwood maximum initial loss parameters

Data Requirement	Neighbourhood 1 – residential	Neighbourhood 2 – commercial	Neighbourhood 3 – industrial
Roof area maximum initial loss (mm)	1	1	1
Paved area maximum initial loss (mm)	2	2	2
Road area maximum initial loss (mm)	2	2	2

If you are using the worksheets, on the Calibration Variables worksheet, enter the roof, paved, and road areas maximum initial loss within the neighbourhood in the equivalent fields in the Stormwater frame section of the worksheet.

Estimating effective impervious surface area

The effective impervious surface area is the percentage of the impervious surfaces that is connected directly to a stormwater drainage system. The concept of effective impervious area has been used in several rainfall-runoff models, such as ILLUDAS (Maidment, 1993), ILLSAX (O'Loughlin, 1991), STORM (Abbott, 1977; Dendrou, 1982), and SWMM (Metcalf & Eddy Inc et al., 1971) and Aquacycle (Mitchell, 2000).

The percentage of impervious surfaces that are directly connected to the drainage system varies greatly. In one survey of nine Australian urban neighbourhoods, Boyd et al. (1993) found that the proportion of impervious area directly connected ranged from 31% to 100%.

Table 12 lists the initial estimates of effective impervious surface parameters within the Heatherwood development project.

Table 12 : Estimated Heatherwood effective impervious surface parameters

Data Requirement	Neighbourhood 1 – residential	Neighbourhood 2– commercial	Neighbourhood 3– industrial
Effective roof area (%)	80	100	80
Effective paved area (%)	40	100	40
Effective road area (%)	90	90	100

If you are using the worksheets, on the Calibration Variables worksheet, enter the percentage of the effective roof, paved, and road areas within the neighbourhood in the equivalent fields in the Stormwater frame section of the worksheet.

Estimating base flow characteristics

Base flow is the amount of water drained from the groundwater store that contributes to the total stormwater flow. To represent the amount of base flow, UVQ requires that you provide an initial estimate of the:

- base flow index (or drainage factor if using two layer soil store)
- base flow recession constant.

The base flow index is the proportion of excess water from the soil stores which recharges the groundwater. The base flow recession constant is the rate at which water leaves the groundwater store and contributes to the stormwater flowing out of the neighbourhood.

Table 13 is the initial estimate of the base flow characteristics within the Heatherwood Development Project neighbourhoods.

Table 13 : Estimated Heatherwood baseflow characteristics

Data Requirement	Neighbourhood 1 – residential	Neighbourhood 2– commercial	Neighbourhood 3– industrial
Base Flow Index	0.45	0.45	0.45
Base Flow Recession Constant	0.00001	0.00001	0.00001

If you are using the worksheets, on the Calibration Variables worksheet, enter the base flow characteristics for each neighbourhood in the stormwater frame.

Defining the other contaminant characteristics

The way water flows through a water system affects the movement and distribution of contaminants. You must define certain contaminant concentrations and loads present in the flow paths of the water cycle. Table 14 outlines the other contaminant values within the water system for the Heatherwood Development Project.

Whilst different rainwater, imported water, evaporation and groundwater concentrations can be specified for each neighbourhood the **template** function can be used to specify identical values for the entire study area.

Table 14 : Heatherwood contaminant values.

Field	Neighbourhood 1 – Residential	Neighbourhood 2 - Commercial	Neighbourhood 3 - Industrial
Other Contaminants frame – Physical Characteristics... screen			
Road runoff (mg/L)	N = 1.6 P = 0.21 SS = 75	N = 1.6 P = 0.21 TSS = 75	N = 1.6 P = 0.21 TSS = 75
Roof first flush (mg/L) (assumed to be twice concentration of runoff)	N = 3.2 P = 0.42 SS = 150	N = 3.2 P = 0.42 SS = 150	N = 3.2 P = 0.42 SS = 150
Roof runoff (mg/L)	N = 1.6 P = 0.21 SS = 75	N = 1.6 P = 0.21 SS = 75	N = 1.6 P = 0.21 SS = 75
Fertiliser to garden (mg/m ²)	N = 0 P = 0 SS = 0	N = 0 P = 0 SS = 0	N = 0 P = 0 SS = 0
Fertiliser to POS (public open space) (mg/ha)	N = 0 P = 0 SS = 0	N = 0 P = 0 SS = 0	N = 0 P = 0 SS = 0
Evaporation (mg/L) Set evaporation to zero	N = 0 P = 0 SS = 0	N = 0 P = 0 SS = 0	N = 0 P = 0 SS = 0
Ground water (mg/L)	N = 0.11 P = 0.007 SS = 0.26	N = 0.11 P = 0.007 SS = 0.26	N = 0.11 P = 0.007 SS = 0.26
Imported (mg/L)	N = 0.11 P = 0.007 SS = 0.26	N = 0.11 P = 0.007 SS = 0.26	N = 0.11 P = 0.007 SS = 0.26

Rainfall (mg/L)	N =1.33 P = 0.87 SS = 17	N =1.33 P = 0.87 SS = 17	N =1.33 P = 0.87 SS = 17
Pavement runoff (mg/L)	N = 1.6 P = 0.21 SS = 75	N = 1.6 P = 0.21 SS = 75	N = 1.6 P = 0.21 SS = 75
Contaminant soil store removal frame – Calibration Variables screen			
Contaminant values (mg/L)	N 40 P 70 SS 70	N 40 P 70 SS 70	N 40 P 70 SS 70

If you are using the worksheets, enter the contaminants on the worksheets corresponding with the relevant screen.

Observed neighbourhood and study area flow and contaminant concentrations

UVQ does not require that you specify the average volumes of imported water, stormwater and wastewater for each neighbourhood and the study area to carry out a simulation. For new build developments actual measurement of these values will not be possible. However, these values are useful to provide a first cut cross check of simulated values when calibrating UVQ, and so some estimation of their value is recommended (design parameters may be available)

Average volumes

Table 15 estimates the average volumes of imported water wastewater and stormwater flowing into and out of the Heatherwood development project neighbourhoods and study area.

Table 15 : Heatherwood average volumes

Data Requirement	Study Area	Neighbourhood 1 – residential	Neighbourhood 2– commercial	Neighbourhood 3– industrial
Observed imported water (ML/y)	523	190	18	315
Observed wastewater (ML/y)	438	115	3	438
Observed stormwater (ML/y)	877	285	27	565

If you are using the worksheets, on the Calibration Variables worksheet, enter the average volume of imported water, wastewater and stormwater for each neighbourhood and the study area in the average volumes frames.

Observed concentrations of imported water, wastewater and stormwater

Table 16 shows the estimates of the average concentrations of imported water, wastewater and stormwater generated within the Heatherwood development project neighbourhoods and study area.

Table 16 : Observed Heatherwood contaminant concentrations.

Field	Neighbourhood 1 – Residential	Neighbourhood 2 - Commercial	Neighbourhood 3 - Industrial
Observed neighbourhood contaminants Quality frame – Calibration Variables screen			
Observed Wastewater (mg/L)	N 57 P 7.3 SS 266	N 52 P 13 SS 392	N 100 P 12 SS 406
Observed Stormwater (mg/L)	N 7.2 P 0.39 SS 88	N 0.57 P 0.29 SS 120	N 7.2 P 1.16 SS 157
Observed study area contaminants Quality frame – Calibration Variables screen			
Observed Wastewater (mg/L) (Average domestic)	N 91 P 11 SS 376		
Observed Stormwater (mg/L) (Australian mean)	N 7.0 P 0.88 SS 133		

If you are using the worksheets, enter the contaminants on the Calibration variables worksheet.

Tutorial 1: Conventional servicing

There follows a tutorial in which the previously described Heatherwood Development project is used as a case study. It is recommended that you read all prior sections of the User Manual prior to beginning the tutorial to ensure the concepts of the model are understood.

Open the tutorial file

1. Open UVQ
2. From the **File** drop down menu, click the **Open Project...** option. Open **Tutorial1.uvq** which will be located in the input directory of your installation package.

Project Information screen

3. From the **Edit** drop down menu, select the **Project...** option and the screen below will be shown.

Here you can specify the area, number of neighbourhoods within the area, Soil Store Type, and Contaminants. The information for the Heatherwood Development project is given as below. Fields with a yellow background are mandatory.

Project Information - [Heatherwood Development Tutorial 1]

Project Description: Heatherwood Development Tutorial 1

Study Area Size: 143 ha

Number of Neighbourhoods: 3

Soil Store Type: ☒ Partial Area ☐ Two Layer

Contaminants

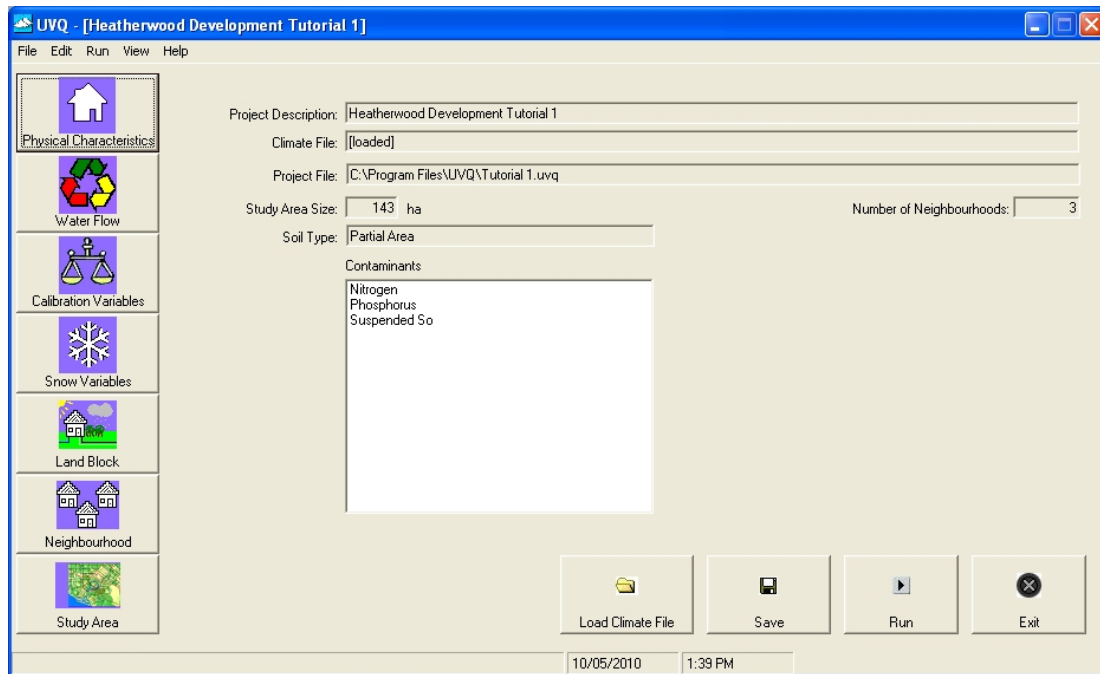
Active	Short name	Long name	Active	Short name	Long name
<input type="checkbox"/>	B	Boron	<input type="checkbox"/>	TOC	Total Organi
<input type="checkbox"/>	K	Potassium	<input type="checkbox"/>	F. St	Faecal Strep
<input type="checkbox"/>	Na	Sodium	<input type="checkbox"/>	End.	Endocrine Di
<input type="checkbox"/>	Cl	Chloride	<input type="checkbox"/>	Virus	Virus
<input checked="" type="checkbox"/>	N	Nitrogen	<input type="checkbox"/>		
<input checked="" type="checkbox"/>	P	Phosphorus	<input type="checkbox"/>		
<input checked="" type="checkbox"/>	SS	Suspended So	<input type="checkbox"/>		
<input type="checkbox"/>	SO4(2-	SO4(2-			

OK Cancel

4. Click the **Cancel** button to return to the Main screen without saving any changes.

UVQ Main screen

The main UVQ screen provides a summary of project information, provides access to all other UVQ functions, provides the facility to load different climate files and allows you to **Save** and **Run** projects. The large buttons on the left hand side of the screen (the UVQ toolbar) access all the data input screens (as does the Edit drop down menu).



Physical Characteristics screen

5. From the toolbar buttons at the left of the Main screen, click **Physical Characteristics**.

The Physical Characteristics Screen provides the detail on the land blocks, occupancy, water usage and contaminant profiles for the different water streams. This information is generated from known parameters of the study area or literature values. A contaminant database is provided with UVQ to provide information on contaminant concentrations which may not be available for the study area. The Physical Characteristics screen for Neighbourhood 1 (the residential neighbourhood) of the Heatherwood Development project is shown below.

Physical Characteristics of Land Blocks and Neighbourhoods - [Heatherwood Development Tutorial 1]

1 | 2 | 3

Measured Quantities for Neighbourhood 1

Neighbourhood
Total Area: 57.4675 ha
Road Area: 11.378 ha
Open Space Area: 2 ha
Percentage of Open Space Irrigated: 100 %
Imported Supply Leakage: 5 %
Wastewater as Exfiltration: 0.03 ratio

Number of Land Blocks: 711

Land Block(s)
Block Area: 620 m²
Average Occupancy: 3
Garden Area: 370 m²
Roof Area: 200 m²
Paved Area: 50 m²
Percentage of Garden Irrigated: 70 %
Roof Runoff to Spooondrain: ratio

Indoor Water Usage & Contaminants

Kitchen Bathroom Toilet Laundry

13.2 L/c/d

Bathroom Contaminant Loads (mg/c/d)

B	Cl	SS	3990	F. St	
K	N	238	SO4(2	End	
Na	P	42	TDC	Virus	

Other Contaminants

Roof First Flush	Fertiliser to POS	Evaporation	Groundwater	Fertiliser to Garden
Imported	Rainfall	Pavement Runoff	Roof Runoff	Road Runoff

Imported Contaminants (mg/L)

B	Cl	SS	.26	F. St	
K	N	.11	SO4(2	End	
Na	P	.007	TDC	Virus	

Water Outputs

Wastewater from Neighbourhood Goes to: 3

Stormwater from Neighbourhood Goes to: 0

Template OK Cancel

- Click **Cancel** to return to the Main screen without saving any changes.

Calibration Variables screen

- From the toolbar buttons at the left of the Main screen, click **Calibration Variables**.

The calibration screen provides information on calibration variables used to calibrate UVQ to data collected from the study area. The observed values in the calibration screen are those recorded from the study area and are entered to provide an easy cross check of modelled versus actual values. The Calibration screen for the Heatherwood Development project is shown below.

Calibration Variables - [Heatherwood Development Tutorial 1]

1 2 3

Calibration Neighbourhood 1

Stormwater

Percentage Area of Soil Store 1: 15 %

Capacity of Soil Store 1: 150 mm

Capacity of Soil Store 2: 300 mm

Roof Area Maximum Initial Loss: 1 mm

Effective Roof Area: 80 %

Paved Area Maximum Initial Loss: 2 mm

Effective Paved Area: 40 %

Road Area Maximum Initial Loss: 2 mm

Effective Road Area: 90 %

BaseFlow Index Ratio: 0.45 ratio

Base Flow Recession Constant: 0.00001 ratio

Contaminant Soil Store Removal %

Set Soil Removal Capacity to 100%

B: 0 Cl: 0 SS: 70 F. St: 0

K: 0 N: 40 SO4(2): 0 End: 0

Na: 0 P: 70 TOC: 0 Virus: 0

Wastewater

Infiltration Index: 0.05 ratio

Infiltration Store Recession: 0.1 ratio

Percentage Surface Runoff as Inflow: 3 %

Dry Weather Overflow Rate: 0 %

Wastewater System Capacity: ☐ Enabled kL

Irrigation

Garden Trigger to Irrigate: 0.5 ratio

Open Space Trigger to Irrigate: 0.5 ratio

this Neighbourhood | Study Area

Average Volumes

Units Scale: ☐ kL/y ☒ ML/y

Observed Simulated

Imported: 190 ML/y ML/y

Wastewater: 115 ML/y ML/y

Stormwater: 285 ML/y ML/y

Quality

☒ Conc. mg/L ☐ Load Kg/y

Wastewater Stormwater

	Observed	Simulated	Observed	Simulated
Boron	0		0	
Potassium	0		0	
Sodium	0		0	
Chloride	0		0	
Nitrogen	57		7.2	
Phosphorus	7.3		0.39	
Suspended	266		88	
SO4(2)	0		0	
Total Organi	0		0	
Faecal Strep	0		0	
Endocrine Di	0		0	
Virus	0		0	
	0		0	
	0		0	
	0		0	

Run Template OK Cancel

Calibration is necessary because UVQ model algorithms contain a number of parameters that are not directly measured in the field and you need to calibrate the model to your local conditions. This section shows you how to calibrate the model to match the observed wastewater, stormwater and imported water quantities within your local area. This represents a simple approach to calibration. UVQ does not have any auto-calibration capabilities, hence calibration of UVQ is a manual, trial and error process.

If you have time series data of any of your stormwater, wastewater or imported water flows, or irrigation requirements, it is strongly recommended that you use more complex calibration verification techniques commonly used in water resources modelling. Simulation data for this more complex calibration process can be found in the output files produced by UVQ.

Because UVQ simulates an integrated water system which accounts for the interactions between stormwater, wastewater and water supply, an individual calibration parameter can influence more than one of the simulated output flows. As a result, an iterative approach to parameter calibration is suggested.

Within the **Calibration Variables** screen, notice how the variables that most influence the volume of stormwater generated are grouped in the **Stormwater** frame, variables that most influence the volume of wastewater

are grouped in the **Wastewater** frame and variables that influence the imported water volume area grouped in the **Irrigation** frame.

The following directions show After you have simulated your conventional water system for the first time, you need to check whether the **Observed** values within the **Average Volumes** frame in the Calibration variables screen match the **Simulated** values for each Neighbourhood and the Study Area. When the observed and the simulated values do not match, you need to alter the stormwater, wastewater and imported water calibration variables and recheck input data values.

To obtain an optimum parameter set:

8. Enter initial estimates of calibration parameter values, ascertained from local knowledge and modelling experience. Initial values for the Heatherwood Development project are already loaded with the project file.
9. Click the **Run** button at the bottom of the Calibration screen to simulate your conventional water system for the first time. Run for the total 25 year climate file, do not select Daily, Monthly and Yearly output files. Also prefix all output files with the test 'Heatherwood base'.

Prefix all results files with the text 'Heatherwood base'

Do not select Daily, Monthly and Yearly output files at this stage

Model Running Parameters - [Heatherwood Development Tutorial 1]

Climate File Date Range Available for Simulation

STARTING YEAR: 1960 ENDING YEAR: 1985

Simulation Date Range

Start Year: 1960 End Year: 1985

Results Options

Prefix all Results filenames with the following text: Heatherwood base

Produce Output Result Files

☒ Daily ☐ Monthly ☐ Annual and Total Run

OK Cancel

Completion:

10. Once you have run the model, a small dialog declares "Finished Calculations. Click **OK** to close it. On the Calibration Variable screen and compare the observed and simulated output values in both the Average Volumes panel for water flows, and in the Quality panel for contaminants.

Calibration Variables - [Heatherwood Development Tutorial 1]

1 | 2 | 3

Calibration Neighbourhood 1

Stormwater

Percentage Area of Soil Store 1: 15 %

Capacity of Soil Store 1: 150 mm

Capacity of Soil Store 2: 300 mm

Roof Area Maximum Initial Loss: 1 mm

Effective Roof Area: 80 %

Paved Area Maximum Initial Loss: 2 mm

Effective Paved Area: 40 %

Road Area Maximum Initial Loss: 2 mm

Effective Road Area: 90 %

BaseFlow Index Ratio: 45 ratio

Base Flow Recession Constant: 0.00001 ratio

Contaminant Soil Store Removal %

Set Soil Removal Capacity to 100%

B: [] Cl: [] SS: 70 F. St: []

K: [] N: 40 SO4(2): [] End: []

Na: [] P: 70 TOC: [] Virus: []

Wastewater

Infiltration Index: .05 ratio

Infiltration Store Recession: .1 ratio

Percentage Surface Runoff as Inflow: 3 %

Dry Weather Overflow Rate: 0 %

Wastewater System Capacity: [] Enabled [] kL

Irrigation

Garden Trigger to Irrigate: .5 ratio

Open Space Trigger to Irrigate: .5 ratio

this Neighbourhood | Study Area

Average Volumes

Units Scale: ☐ kL/y ☒ ML/y

Observed Simulated

Imported: 190 ML/y 191 ML/y

Wastewater: 115 ML/y 116 ML/y

Stormwater: 285 ML/y 289 ML/y

Quality

☒ Conc. mg/L ☐ Load Kg/y

Wastewater Stormwater

Observed Simulated Observed Simulated

Boron [] [] [] []

Potassium [] [] [] []

Sodium [] [] [] []

Chloride [] [] [] []

Nitrogen 57 96.00 7.2 1.55

Phosphorus 7.3 12.00 .39 0.296

Suspended 266 352.0 88 66.65

SO4(2) [] [] [] []

Total Organic [] [] [] []

Faecal Strept [] [] [] []

Endocrine Disruptors [] [] [] []

Virus [] [] [] []

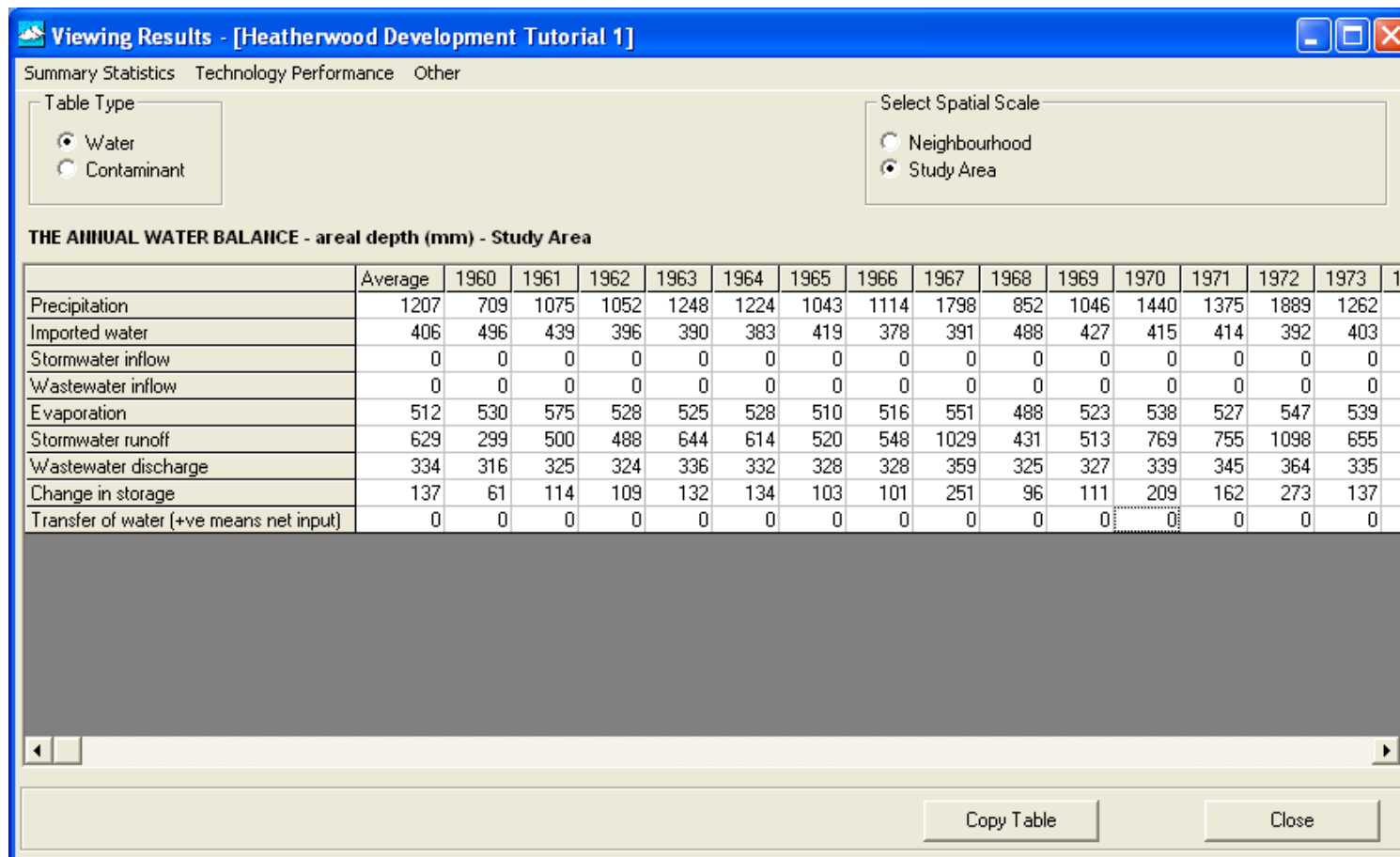
Run Template OK Cancel

11. The Observed and Simulated stormwater, wastewater and imported water volumes are a good match for Neighbourhood 1, 2 and 3. If in your study there is not a good match then vary the calibration parameters in the wastewater and stormwater frames to match until the simulated wastewater volume and the observed wastewater volume match. Be consistent in your approach and only vary one parameter at a time
12. Re-Run the simulation and check whether the observed and simulated wastewater volumes now match.
13. At the end of this process, you will have a complete set of initial parameters. This iterative process should continue until all three simulated outputs are fitted as well as possible. In the later iterations of this process, the effect of any change in each calibration parameter value should be assessed in terms of the impact on all three outputs. If the new parameter value improved the fit of one of the outputs but has a significant negative impact on one or two of the outputs the new value should not be used.
14. A similar process can be used for the contaminants, although if literature values have been used for input loads and concentrations you may need to change these in the Physical Characteristics screen until a match between observed and simulated values is achieved.

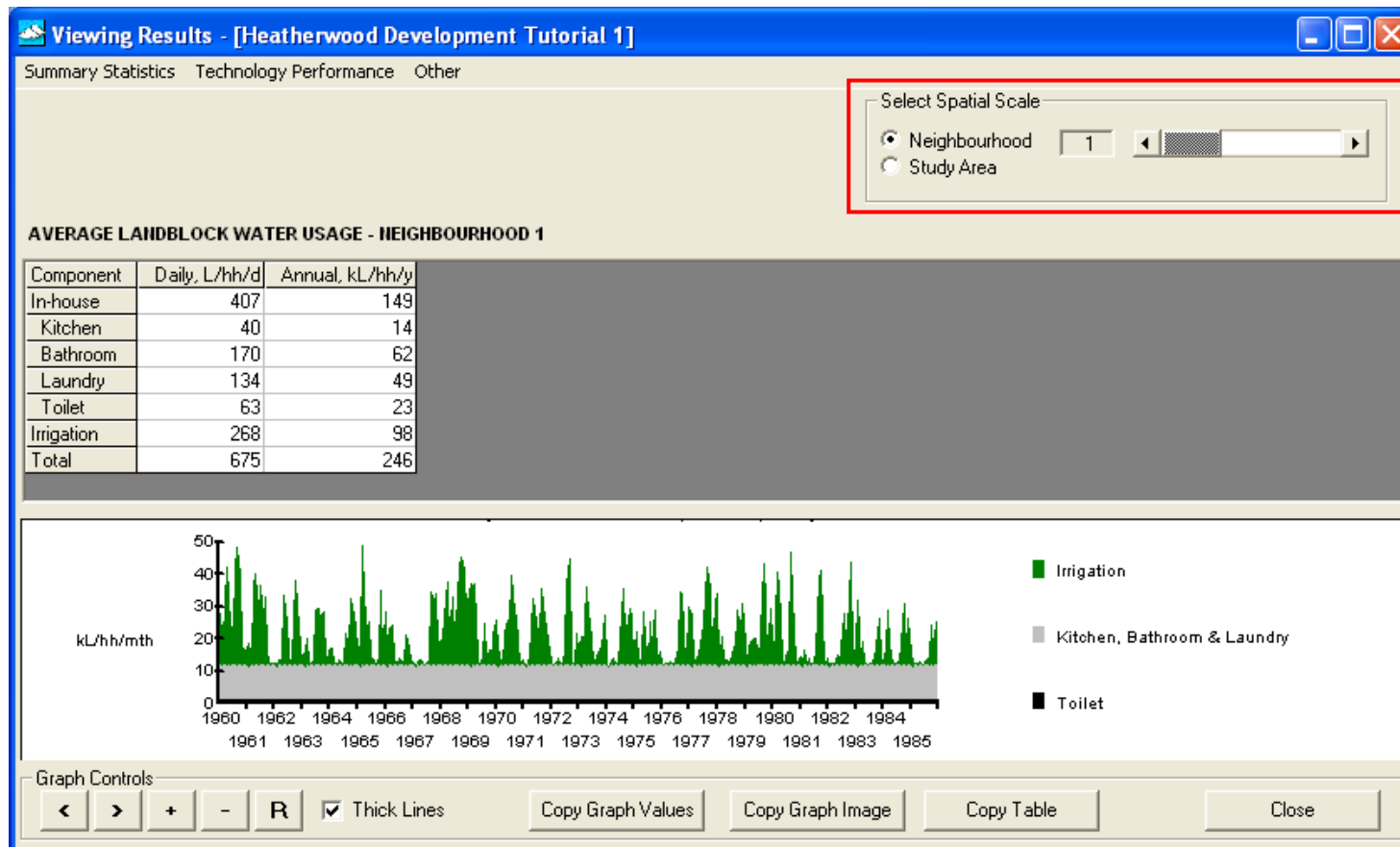
15. Once you have achieved good correlation between observed and simulated values rerun the model with the Daily, Monthly and Yearly output files switched on. Check results in the Results screen or in the output files. For a description of the content of the output files see Results section of this document. The results screen will show you tabulated and graphical water and contaminant balances for each neighbourhood and the entire study area (see below)

Viewing the Results of a Run:

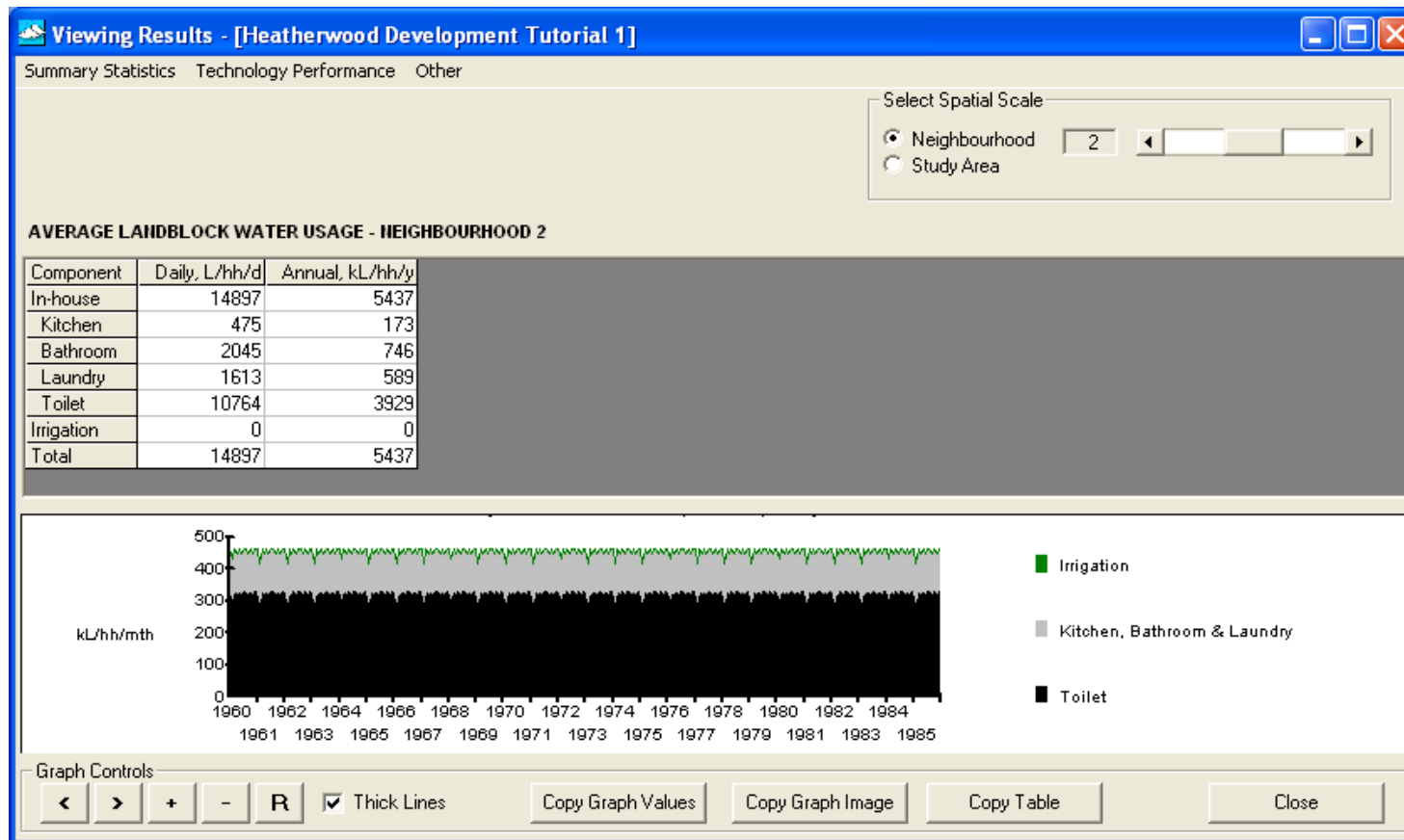
16. Click **OK** to close the Calibration screen, saving the changes since the Run.
17. Click the **View** drop down menu and select the menu option **Results**.
 - a. Results screen 1 screen-shot below, shows the **Summary statistics > Water and Contaminant Balance** screen, the water balance results specifically. You can alternate between water and contaminant results by selecting either option. You can also select whether to examine the results for the entire study area or for each individual neighbourhood. The contaminant results are shown in either loads or concentrations.
 - b. Results screen 2 screen-shot shows the **Summary Statistics > Land Block Water Usage** option for Neighbourhood 1. The graph shows the irrigation demand is highly variable whereas the kitchen bathroom and toilet uses are constant.
 - c. Results screens 3 to 5 show the **Land Block Water Usage** for the other Neighbourhoods and for the entire study area.
 - d. Results screens 6 and 7 show the **Summary Statistics > Land Block Irrigation** and **Summary Statistics > Public Open Space and Household Irrigation** options. These show the monthly irrigation requirements in more detail. The contaminant option in all these results screens will provide detail of the total run contaminant loads or average concentrations.
 - e. Results Screens 8 and 9 provide more detail of the contaminant values. These screens are accessed through the **Other > Other Graphs** option. Data can be presented in a number of ways, histograms, pie graphs or monthly and yearly time series. Many combinations of different sources and uses for the many flow streams can also be selected. The numbering of the flow stream correlates to the identifying numbers used in the contaminant flow diagrams in Appendix I: Contaminant Flow Diagrams.



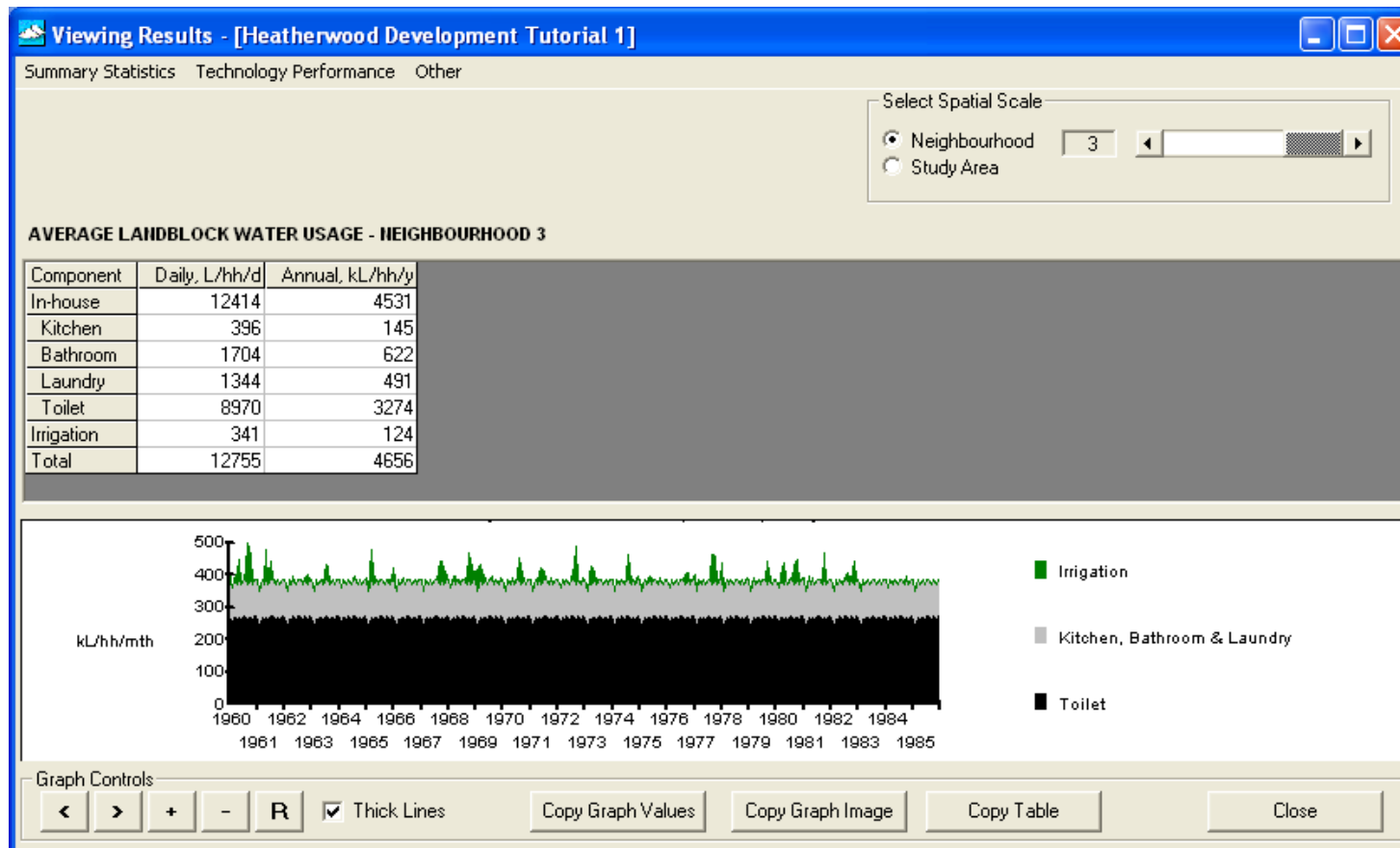
Results screen 1: **Summary statistics > Water and Contaminant Balance**



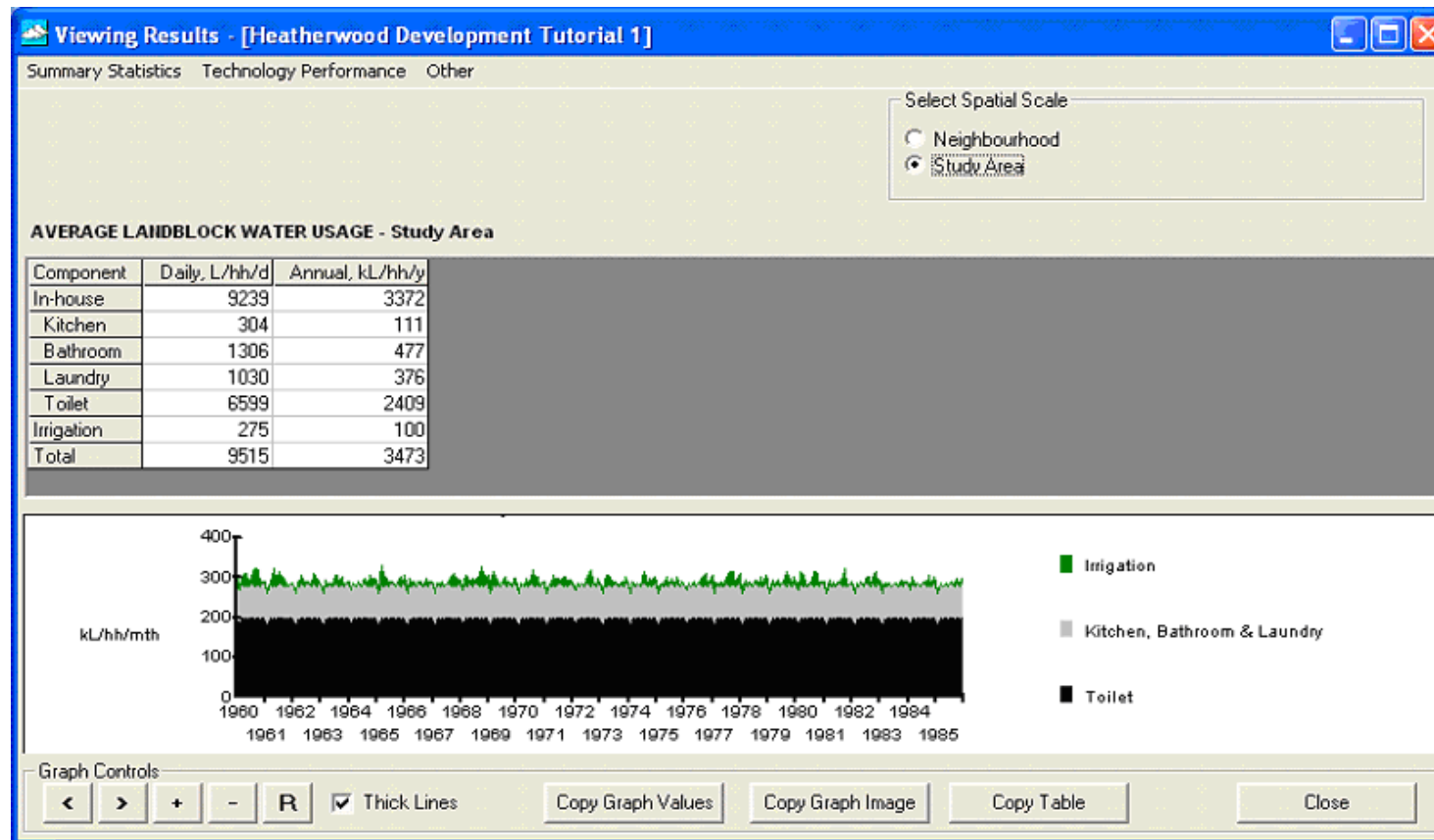
Results screen 2: **Summary Statistics > Land Block Water Usage (Neighbourhood 1)**



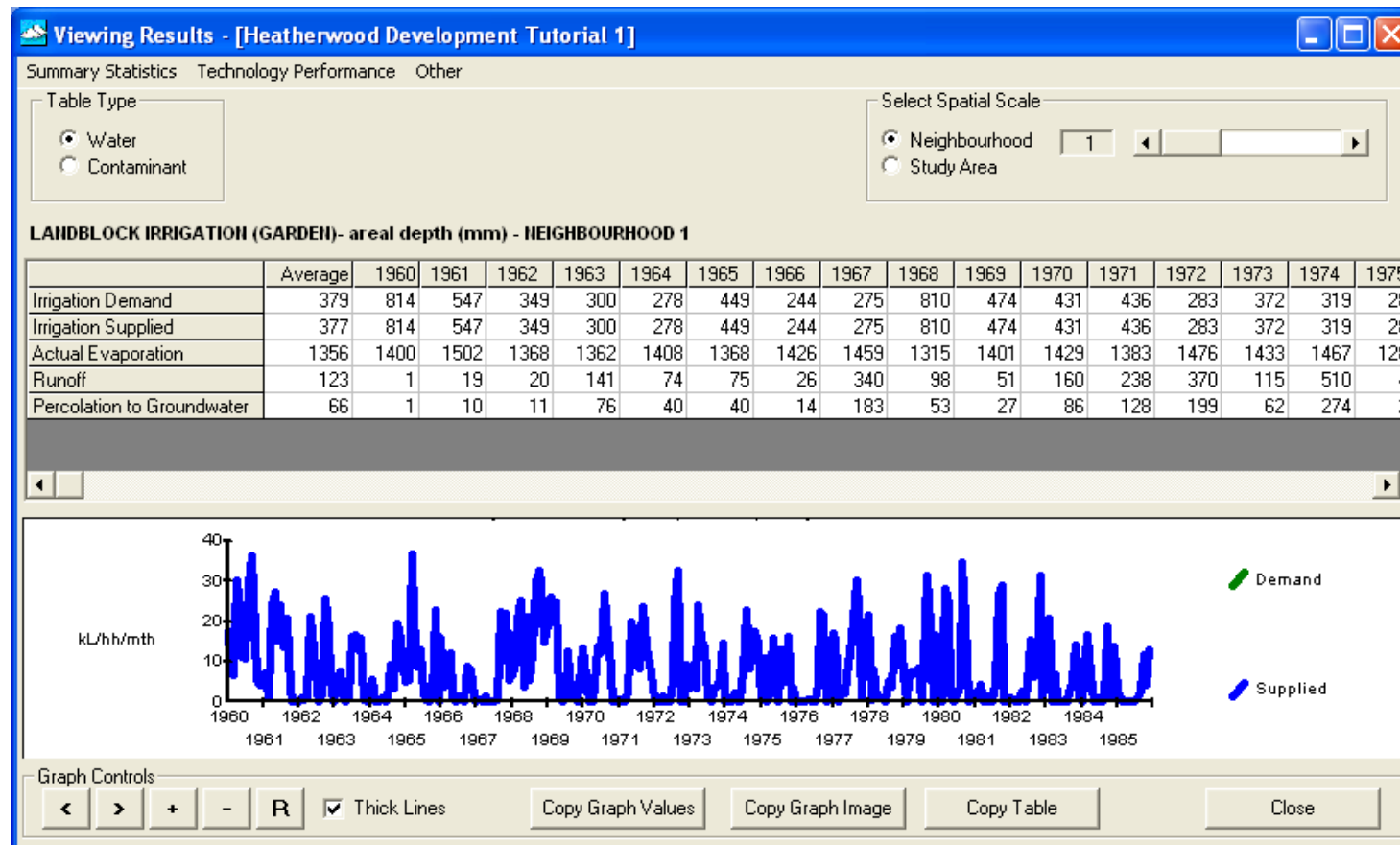
Results screen 3: **Summary Statistics > Land Block Water Usage (Neighbourhood 2)**



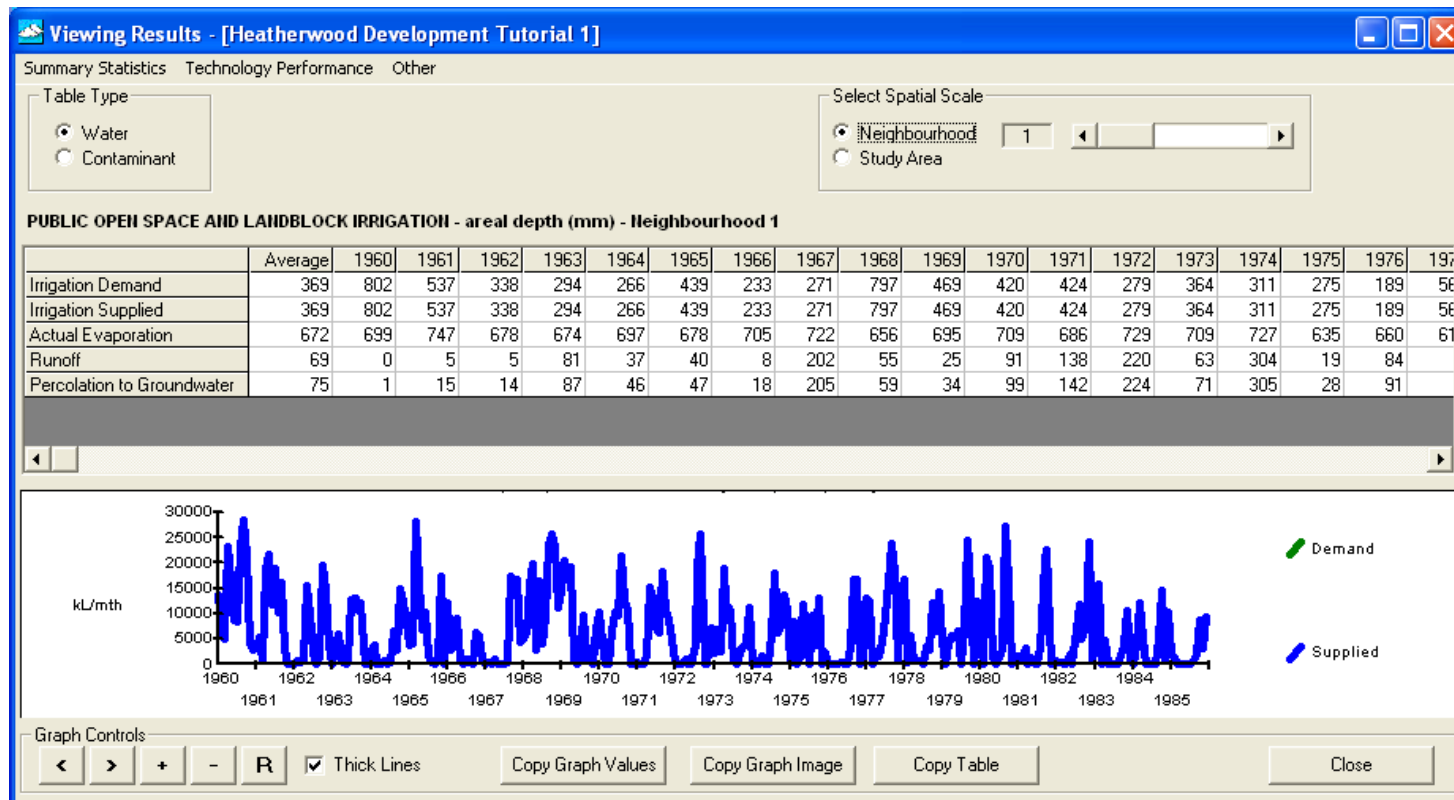
Results screen 4: **Summary Statistics > Land Block Water Usage (Neighbourhood 3)**



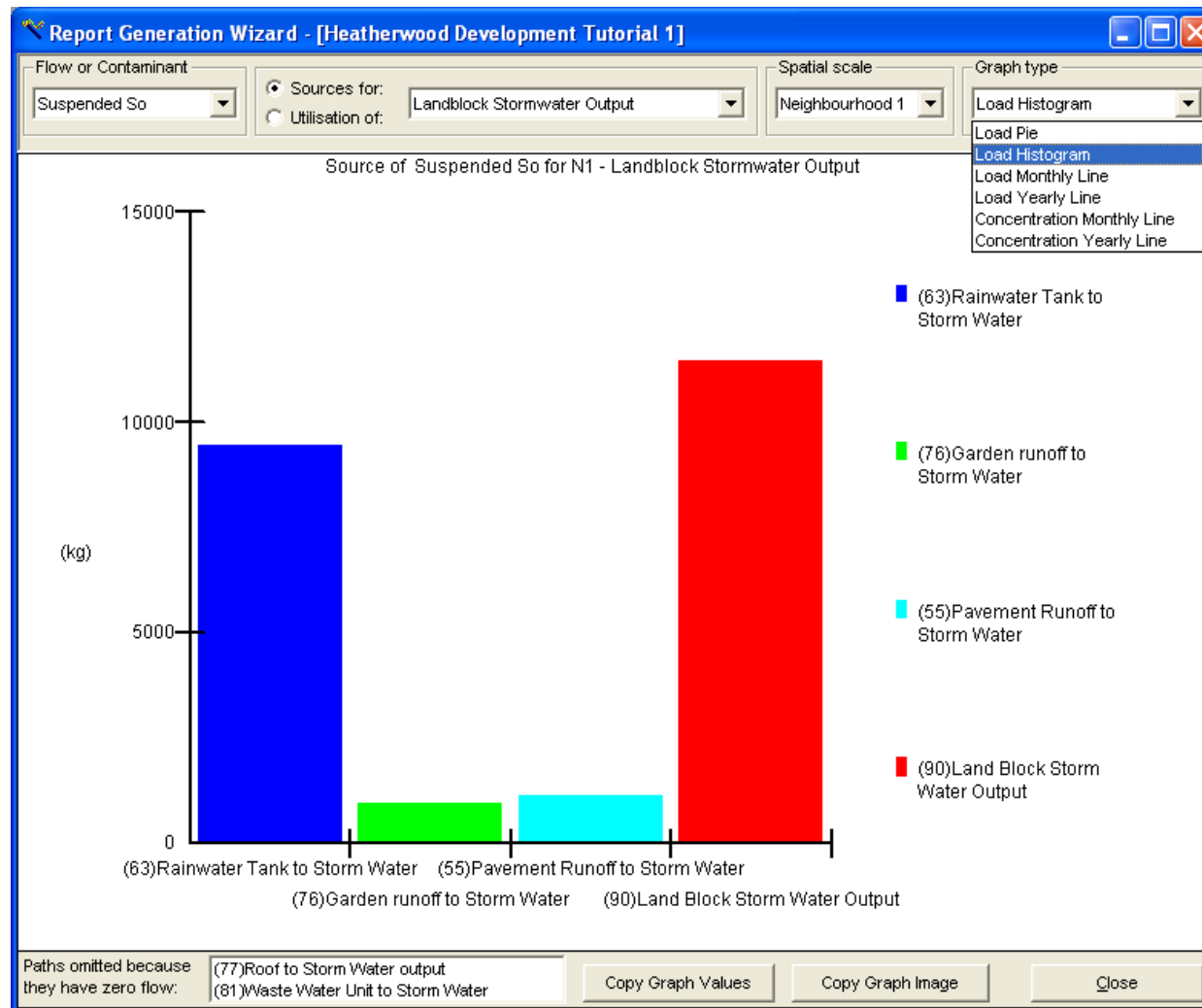
Results screen 5: **Summary Statistics > Land Block Water Usage (whole Study Area)**



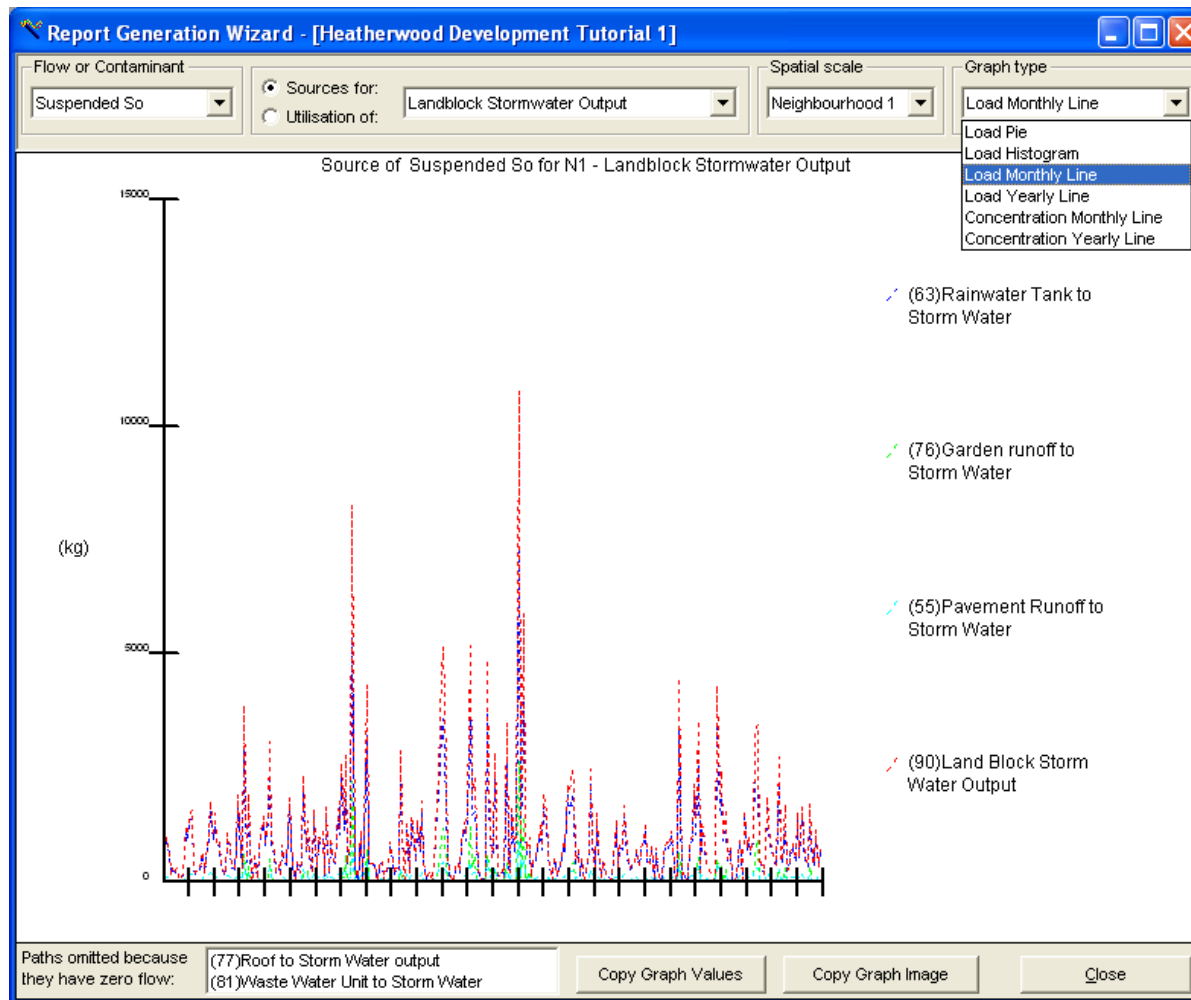
Results screen 6: **Summary Statistics > Land Block Irrigation**



Results screen 7: **Summary Statistics > Public Open Space and Household Irrigation**



Results screen 8: **Other > Other Graphs**



Results screen 9: **Other > Other Graphs**

Tutorial 2: Investigating alternative servicing approaches

Land Block options

The effect of installing a rainwater tank and an on-site wastewater treatment unit on the imported water, stormwater and wastewater flows can be investigated by creating storages in the Land Block Water Management Features screen.

1. Open UVQ
2. From the **File** drop down menu, click the **Open Project...** option. Open **Tutorial2.uvq** which will be located in the input directory of your installation package.
3. From the toolbar buttons on the Main screen, click **Land Block** to view the Land Block Water Management Features screen.

The tutorial file Tutorial2.uvq has 5 kL raintanks for laundry and bathroom uses for all the houses in Neighbourhood 1 and an on-site wastewater treatment plant for toilet flushing and garden irrigation in all the houses in Neighbourhood 1. The on-site wastewater unit will need to treat to a high quality to provide water suitable for use inside the home thus 90% removal for all contaminants is suggested.

Land Block Water Management Features - [Heatherwood Development project]

1 2 3

Land Block(s) within Neighbourhood 1

Rain Tank

Storage Capacity: 5 kL

Initial Storage Level: 0 kL

First Flush: 0 kL

Supplies to:

☒ Bathroom ☒ Stormwater

☒ Laundry ☒ Garden

☐ Kitchen ☐ On site vvw

☐ Toilet

☐ Garden

First Flush to:

Backup Supply from

Storage Backup Trigger Level (ratio): 0

Stormwater Store in Neighbourhood No.: 0

Wastewater Store in Neighbourhood No.: 0

Contaminant Removal Efficiency %

B	0	Cl	0	SS	60	F.Strep	0	N/A	0
K	0	N	30	SO ₄	2	End.dis	0	N/A	0
Na	0	P	30	TOC	0	Virus	0	N/A	0

Sub Surface Greywater Irrigation

Collected from: ☐ Kitchen ☐ Bathroom ☐ Laundry

On Site Wastewater Unit

Storage Capacity: 5 kL

Exposed Surface: 0 m²

Initial Storage Level: 0 kL

Treat the Following Sources:

☒ Bathroom

☒ Laundry

☒ Kitchen

☒ Toilet

Supplies to:

☒ Toilet

☒ Garden

Excess Drain to:

☐ Stormwater

☒ Wastewater

☐ Leachfield

Contaminant Removal Efficiency %

B	0	Cl	0	SS	90	F.Strep	0	N/A	0
K	0	N	90	SO ₄	2	End.dis	0	N/A	0
Na	0	P	90	TOC	0	Virus	0	N/A	0

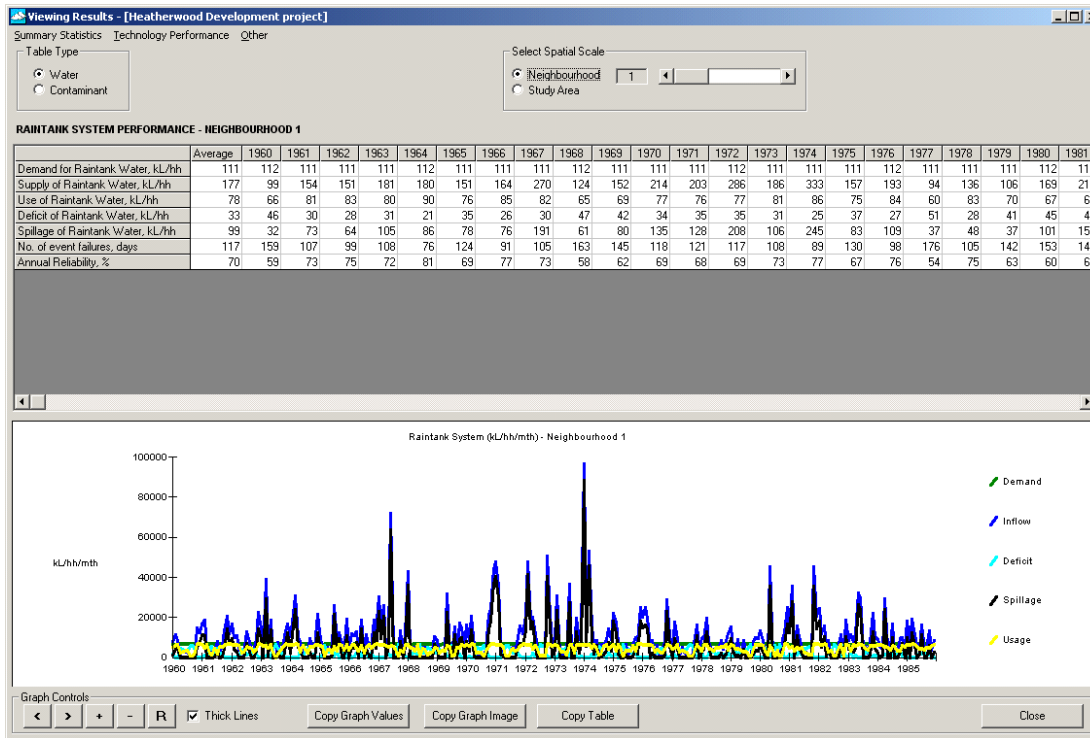
Imported Water

☐ Supplies Garden Irrigation

Template OK Cancel

4. **Run** the model, then check the effect on total water and wastewater flows in the **Calibration Variable** screen.
5. For more detailed results go to the **Results** Screen via the **View** menu, then select the **Technology Performance > Rainwater Tank** or **> On-site wastewater**

drop down menu item. The results are shown in Results Screens 10 and 11 below.



Results Screen 10: Technology Performance > Rainwater Tank

Viewing Results - [Heatherwood Development project]

Summary Statistics Technology Performance Other

Table Type

☐ Water

☒ Contaminant

Contaminant Metrics

☒ Kg/y

☐ T/y

Monitoring

☒ Load

☐ Concentration (mg/L)

Select Spatial Scale

☒ Neighbourhood 1

☐ Study Area

On-site Wastewater - Average Annual Contaminant LOAD for Neighbourhood 1

	Nitrogen	Phosphorus	Suspended Solids
Indoor to on-site WWT	11544.7	1398.0	43209.2
Raintank first flush to on-site WWT	0	0	0
Sludge	10390.2	1258.2	38888.2
Retained Contaminants	0	0	0
On-site wwt to garden	524.0	63.44	1947.3
On-site wwt to sewerage system	451.9	54.74	1704.5
On-site wwt to stormwater system	0	0	0

Copy Table

Close

Results Screen 11: Technology Performance > On-site wastewater

Exercise 1

As is demonstrated by the graph and the statistics on the above screen, the 5kL Rainwater Tank cannot meet the bathroom and laundry demands. As an exercise, incrementally upsize the Rainwater Tank until Average Annual Reliability is increased to 90%. Also try amending the first flush value and assume tank is full at beginning of each run.

Exercise 2

As is demonstrated by the statistics for the on-site wastewater system the majority of contaminants end up as sludge in the system. As an exercise change the removal efficiency of the on-site wastewater unit and /or the concentration of contaminants entering the system (mimicking use of eco-friendly products) and see what effect this has on the sludge produced.

Exercise 3

Try using Sub-Surface Greywater Irrigation rather than an on-site wastewater treatment process for garden irrigation. See what impacts this has on contaminant flows to the garden and sewerage system.

Note: When carrying out the above exercises the Observed values for Imported Water, Wastewater and Stormwater do not correlate with Simulated values. This should not cause any alarm for the user however, because the water flow processes within the Neighbourhood have been altered.

Neighbourhood options

In this section the setting up of a neighbourhood stormwater and wastewater store is described. Using the **Tutorial1.uvq** project file follow the instruction below.

1. Open UVQ
2. From the **File** drop down menu, click the **Open Project...** option. Open **Tutorial1.uvq** which will be located in the input directory of your installation package.
3. From the UVQ toolbar, click the **Neighbourhood** button to open the **Neighbourhood Water Management Features** Screen.
4. Set up a 4000 kL Stormwater Store to Neighbourhood 1. The initial storage can be set at 3500 kL and the exposed surface can be set at 400 m². In this instance, First Flush can be set to zero. The sources of water will be from Road Runoff, Land Block Runoff and Open Space Runoff. The contaminant removal efficiency can be set to 30%, 40% & 60% for N, P & SS respectively.

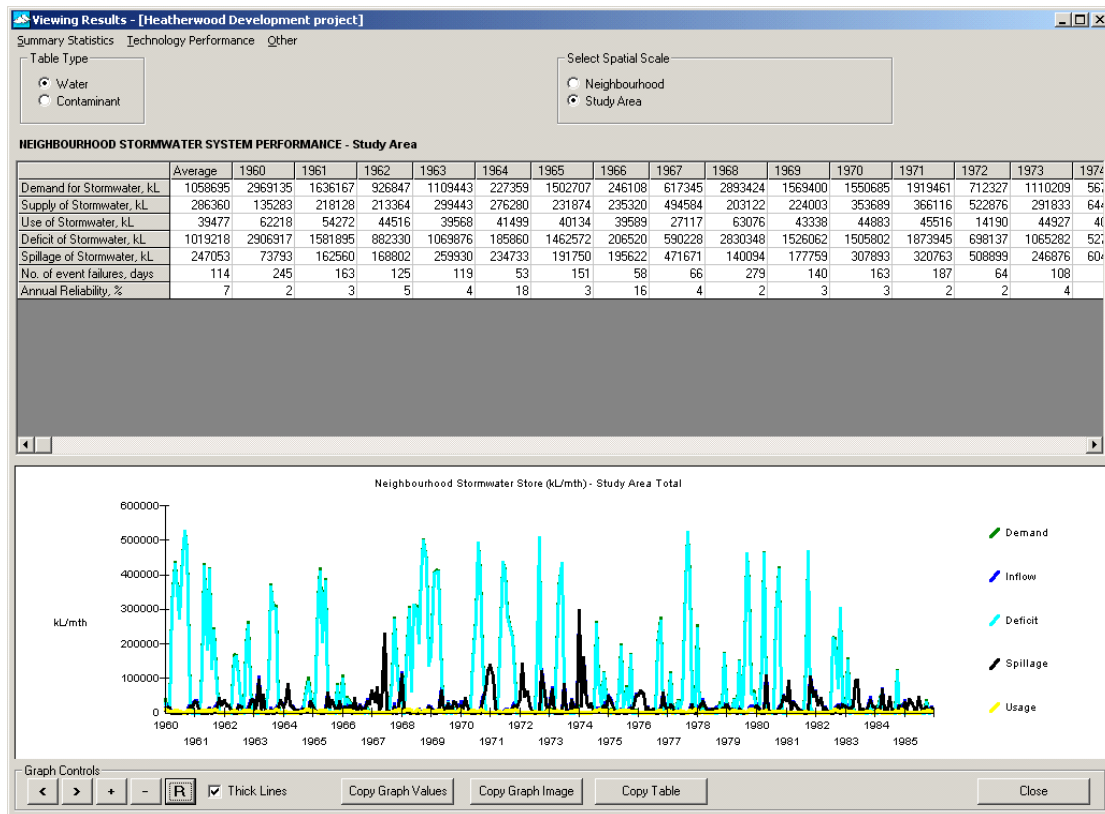
5. Click on the **Select Neighbourhoods** button for Garden Irrigation and highlight Neighbourhood 1. Then click **OK**.
6. Repeat the process for Open Space Irrigation.
7. Now return to the UVQ main screen and click **Run**.
8. Enter a start year of 1960 and an end year of 1985 and click **OK**.
9. Once Run is complete, from **View > Results** screen, select **Technology Performance > Neighbourhood Stormwater**
10. As is demonstrated by the deficit, failure and reliability statistics and the graph, the 4500 kL Stormwater Store cannot meet the demands of open space and garden irrigation.

Exercise 4

As an exercise, remove Garden Irrigation as a demand on the Stormwater Store: click on the **Select Neighbourhoods** button for Garden Irrigation, then click on Neighbourhood 1 so it is not highlighted any more, now click OK. Run the model, then go back to the results screen and see what impact this has.

Exercise 5

As an exercise, try limiting the size of the Stormwater Store as much as possible whilst still maintaining an Average Annual Deficit of zero.



We will now investigate the use of a Neighbourhood Wastewater Store.

11. Before beginning, erase all the information entered in the **Neighbourhood Stormwater Store** screen – setting the Storage Capacity to zero will disable the rest of the stormwater store information.
12. Still on the **Neighbourhood** screen, click on the **Wastewater** tab and create a Wastewater Store of 1000 kL with an exposed surface of 100 m² and an initial storage of 800 kL. The contaminant removal efficiencies can be set at 60%, 50% and 90%.
13. Check the **Collect Wastewater from Land Blocks in this Neighbourhood** box.
14. Click on the **Select Neighbourhoods** tab for **Open Space Irrigation** and highlight Neighbourhood 1.
15. **Run the model**

Neighbourhood Water Management Features - [Heatherwood Development project]

1 | 2 | 3

Neighbourhood 1

Stormwater & ASR | Wastewater | Groundwater & Imported Water

Wastewater Store

Storage Capacity: 1000 kL
Exposed Surface: 100 m²
Initial Storage Level: 800 kL

☒ Collect Wastewater from Land Blocks in this Neighbourhood
☐ Collect Wastewater from Upstream Neighbourhoods
☐ Overflow to Stormwater (Upstream of neighbourhood stormwater store intake)
☒ Overflow to Wastewater

Contaminant Removal Efficiency %

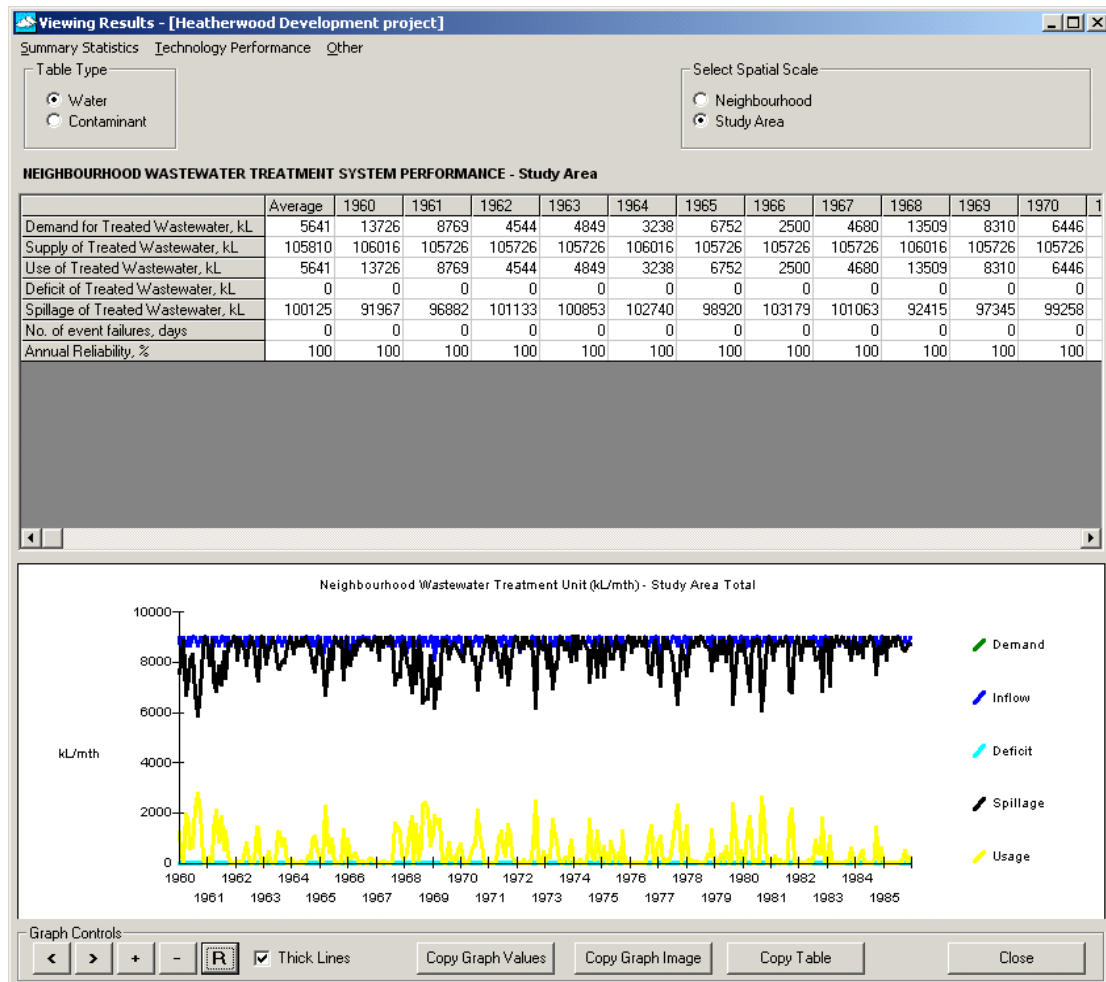
B	0	Cl	0	SS	90	F.Strep	0	N/A	0
K	0	N	60	SD ²⁻⁴	0	End.dis	0	N/A	0
Na	0	P	50	TOC	0	Virus	0	N/A	0

Wastewater Store Supplies Go To

Garden: [] Select Neighbourhoods
Open Space: 1. Select Neighbourhoods
Toilet: [] Select Neighbourhoods

Template OK Cancel

16. Now go to the Viewing Results screen and select **Technology Performance > Neighbourhood Wastewater**. The results screen should look something like this:



Note that Annual Reliability is 100%.

Exercise 6

As an exercise, reduce the size of the Wastewater Store as much as possible whilst retaining an Annual Reliability of 100%. Note the difference in performance between the Wastewater Store and Stormwater Store both in water supply and contaminant removal.

Other Helpful hints

- When setting up your own study area characteristics you should assign each neighbourhood within your study area with a number to correspond with the numbered tabs within each screen before you begin.
- The **Template** button allows you to copy the parameters from one neighbourhood tab to another on the **Physical Characteristics** of Land Blocks and Neighbourhoods screen.

Specify parameters that you know are applicable to more than one neighbourhood i.e. Imported water contaminant concentrations or wastewater as exfiltration. Then click the **Template** button and copy the values to appropriate neighbourhoods:

Use these tabs to enter the data for each neighbourhood.

Remember, fields with a yellow background are mandatory.

Finally, click on the Template button and select Neighbourhoods to copy the data to.

- The land block fields are only enabled when you specify the number of land blocks (greater than 0) within a neighbourhood in the **Number of Land Blocks** field:

Notice how the Land Block fields become active when you specify the Number of land blocks here.

Physical Characteristics of Land Blocks and Neighbourhoods - [Heatherwood Development Project]

1 | 2 | 3

Measured Quantities for Neighbourhood 1

Neighbourhood

Total Area: 57.45 ha

Road Area: 11.378 ha

Open Space Area: 2 ha

Percentage of Open Space Irrigated: 100 %

Imported Supply Leakage: 5 %

Wastewater as Exfiltration: 0.03 ratio

Number of Land Block(s): 711

Land Block:

Block Area: 620 m²

Average Occupancy: 3

Garden Area: 370 m²

Road Area: 200 m²

Paved Area: 50 m²

Percentage of Garden Irrigated: 70 %

Roof Runoff to Spooondrain: 0 ratio

Indoor Water Usage & Contaminants

Kitchen | Bathroom | Toilet | Laundry

56.8 L/c/d

Bathroom Contaminant Loads (mg/c/d)

B: 8303 SS: 8303 F.Strep: N/A

K: 462 N: 462 SO₄²⁻: N/A

Na: 22 P: 22 TOC: N/A

Other Contaminants

Roof First Flush | Fertiliser to POS | Evaporation | Groundwater | Fertilizer to Garden

Imported | Rainfall | Pavement Runoff | Roof Runoff | Road Runoff

Imported Contaminants (mg/L)

B: 0.26 SS: 0.26 F.Strep: N/A

K: 0.11 N: 0.11 SO₄²⁻: N/A

Na: 0.007 P: 0.007 TOC: N/A

Water Outputs

Wastewater from Neighbourhood Goes to:

Stormwater from Neighbourhood Goes to:

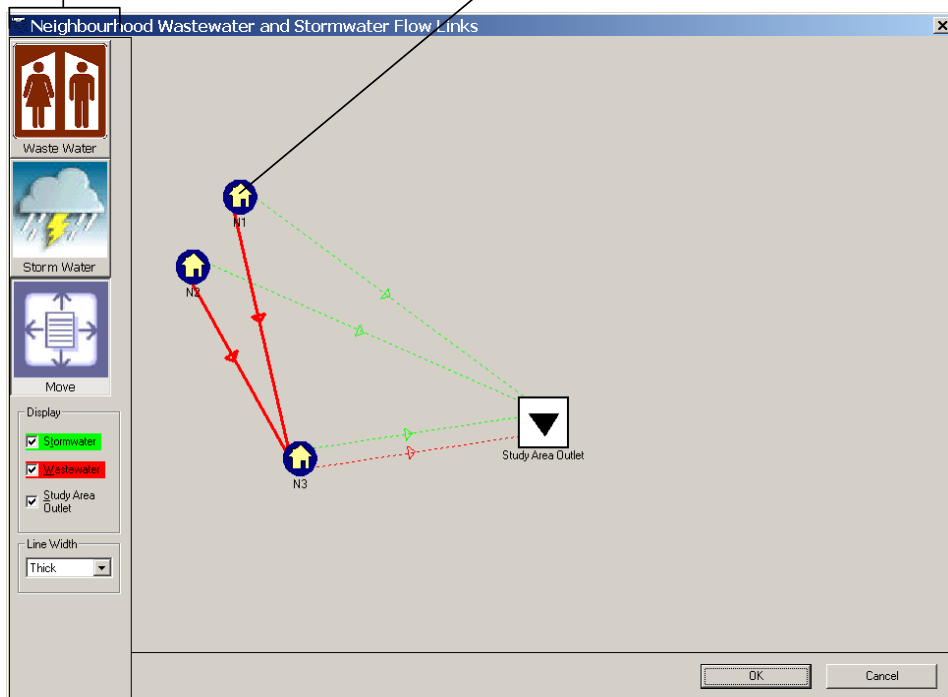
Template OK Cancel

- Remember to save your work regularly. To save your work, return to the main window and click the **Save** button.

- The way the stormwater and wastewater flows between neighbourhoods in the study area is specified in the Neighbourhood Wastewater and Stormwater Flow Links screen:

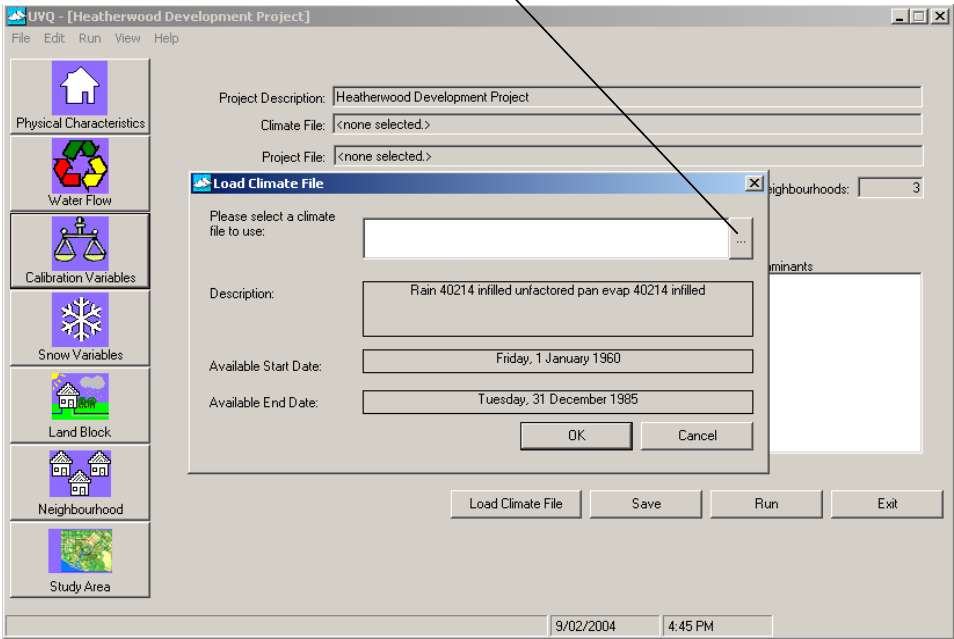
Use these buttons to select the wastewater link edit mode.

Drag and drop the N1 icon on top of the N3 icon to create the wastewater link



- New climate files can be loaded via the option on the File drop down menu or via the button on the UVQ main screen. Only complete year climate files should be used in UVQ. UVQ displays the climate file details in the **Load Climate File** screen. The **Run** option can be used to further define the simulation date range if you require the date range to be smaller than the range within the climate file.

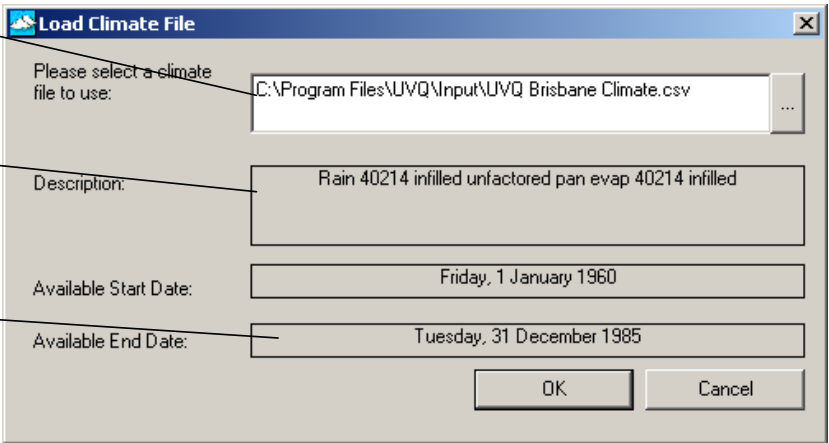
Click the Browse button to open the climate file.



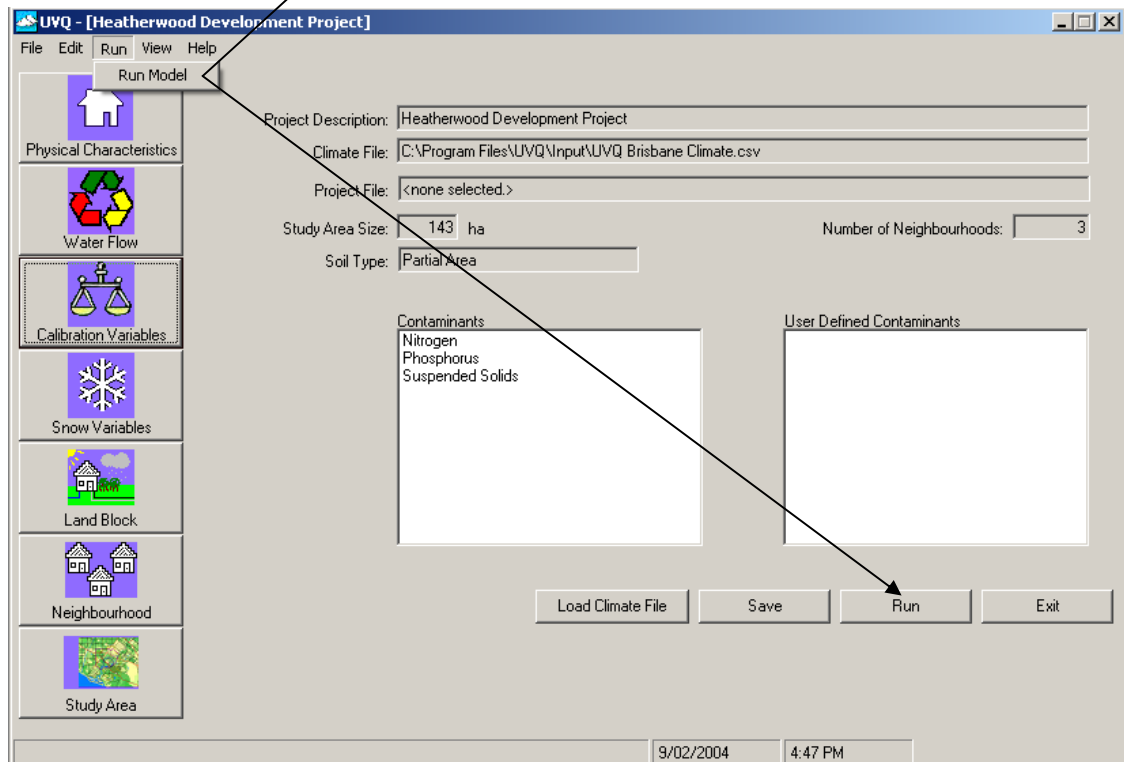
The file name and path is displayed

UVQ displays the first row of the climate file in the description field.

The climate file start and end dates are displayed in the Available Start Date and Available End Dates fields.

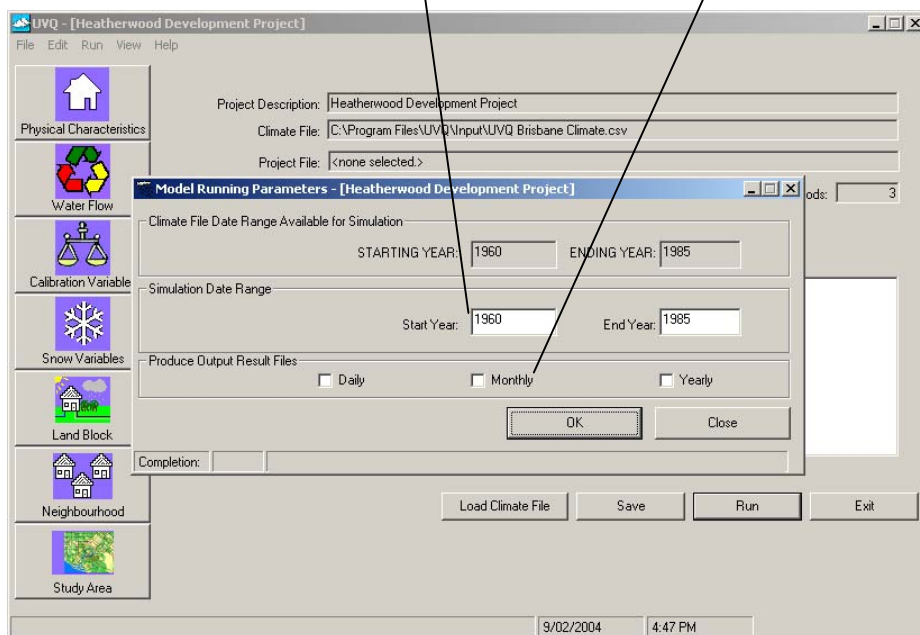


You can use the Run Model menu option to run the model or the Run button. You can also run the model from the Calibration Variables screen.



Change the date range if you want to simulate the climate variables over a specific period.

Specify the time step required for the output files.



Input File Structure

Climate Input File

The climate data file contains historic daily precipitation, potential evaporation, and average temperature data series. Precipitation and potential evaporation are in the units of millimetres per day, while average daily temperature is in the units of degrees Celsius. The series must start at the beginning of a calendar year (1st January) and stop at the end of a calendar year.

The date format used is YYYYMMDD, so 3rd December 1995 is represented as 19951203.

The following is an example of a climate data file:

```
19960101,MTTAMBORINE,20061231,CapodiMonte
```

```
19960101,4.80,3.4,15.25
```

```
19960102,3.86,3.8,16.5
```

```
19960103,84.47,2.6,17.25
```

```
19960104,22.37,1,18
```

```
19960105,5.16,2.2,19
```

```
.....
```

The first line contains the start date, location identifier (climate file key), end date and a dummy text string. The location identifier can be any continuous string of alphanumeric, stating the region that the climate series applies to.

The second to final line contains the date, precipitation, potential evaporation and average daily temperature. It is preferable that the precipitation and potential evaporation and for a given day are the 24 hour measurements for midnight to midnight. Although, 9 am readings (for the 24 hours preceding 9 am) can be used with little impact expected.

Project File

The project file contains all the data input through the UVQ model interface and the climate data. User settings defined in UVQ are saved to this file. The user can create scenarios by changing parameter settings and saving under a different project file name.

Results

UVQ reports results within the interface and also via .csv files.

The types of results generated in the UVQ interface are:

- Summary statistics
- Technology performance

- User defined graphs

Within each of these categories there are a number of tabular and graphical representations of model simulation results as outlined below

Summary Statistics

The summary statistics results reports are:

- Water and contaminant balance
- Climate statistics
- Land block water use
- Land block irrigation
- Public open space and land block irrigation

For more detail of these results screen see Tutorial.

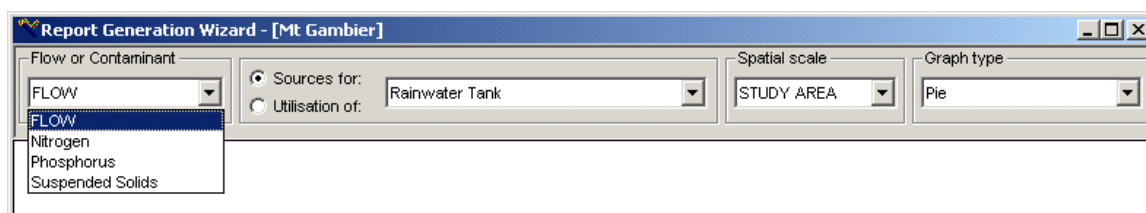
Technology Performance

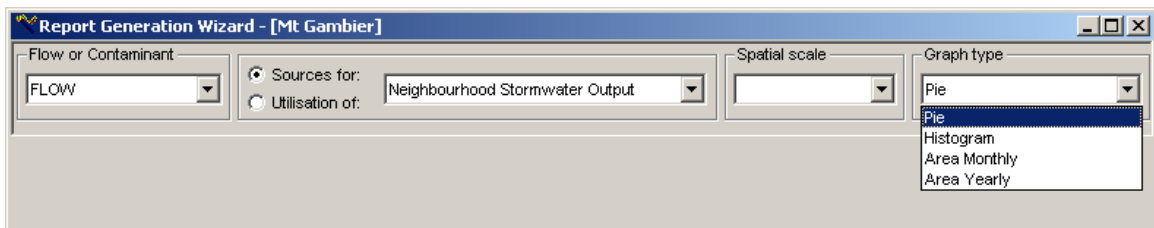
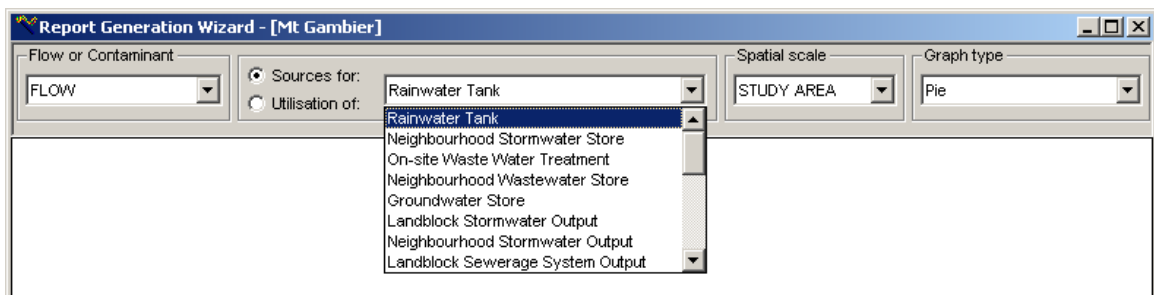
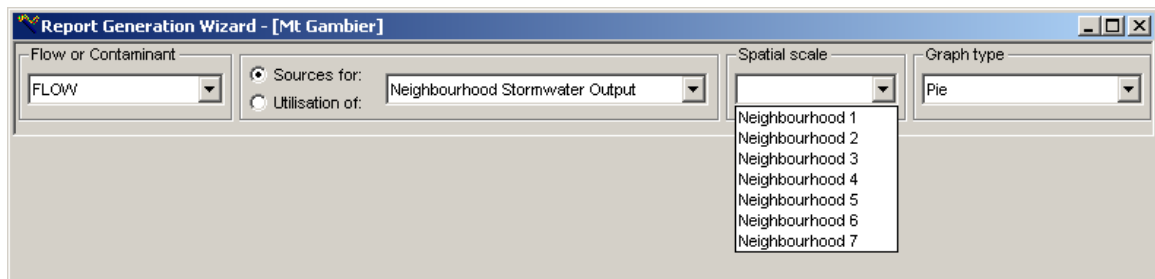
The technology performance results reports are:

- Rain tank
- Sub-surface greywater irrigation
- On-site wastewater
- Neighbourhood stormwater
- Neighbourhood wastewater
- Aquifer storage and recovery
- Study area stormwater
- Study area wastewater

For more detail of these results screen see Tutorial.

User defined graphs





Generated result files

In addition to the results files accessible through the user interface a number of water and contaminant .csv files are generated by UVQ.

The contaminant files are:

- Cont Bal - Neighbourhood N.csv
- Cont Bal - Study area.csv

The water files are:

- StudyAreaBalance.csv
- DailyNeighbourhoodn.csv
- DailyLandBlockn.csv
- MthlyStudyArea.csv
- MthlyNBHn.csv
- YearStudyArea.csv

- YearNBHn.csv

Cont Bal - Neighbourhood N.csv

Where N is the neighbourhood number

This file contains details of all input and output flows and contaminant loads for the total land blocks within neighbourhood N, and the input and output flows for the entire neighbourhood. Flows are reported in kL and masses are reported as raw data values i.e. if input concentrations are specified in mg/L the output loads reported in this file are in mg, or if input concentrations are in cfu/L the outputs loads are in cfu.

This file provides also reports the assumed loads to the roof, paved areas and roads. Contaminant streams reported in this file are detailed below. The numbers associated with the streams are the contaminant profile IDs which can be viewed in the contaminant balance flow sheets (see Appendix I: Contaminant Flow Diagrams).

Land block

- Imported Water (1 + 66)
- Precipitation (50)
- Fertiliser (86)
- Kitchen (33)
- Bathroom (34)
- Laundry (35)
- Toilet (36)
- Assumed pavement load (195)
- Assumed roof load (198)
- Assumed groundwater removal (196)
- Pervious soil store sludge (200)
- Pervious soil store retained volume (93)
- Infiltration (72)
- Raintank sludge (199)
- Raintank retained volume (84)
- Evaporation (91)
- (Other) Neighbourhood SW store in (14 + 79 + 80)
- (Other) Neighbourhood WW store in (73 + 84)
- Study area SW store in (74)
- Study area WW store in (75)
- Stormwater out (90)
- Wastewater out (89)

Neighbourhood

- Imported Water (120 + 115 + 1 + 66)
- Precipitation (100)
- Fertiliser to POS (152)
- Assumed road load (194)
- Assumed groundwater load (192)
- Public open space soil store sludge (202)
- Public open space retained volume (156)
- (Other) Neighbourhood SW store in (136 + 137)
- (Other) Neighbourhood WW store in (142 + 146)
- To land block (50 + 151 + 150 + 99)
- From land block (43 + 133 + 130 + 40 + 122)
- Study area SW store in (111)
- Study area WW store in (110)
- Evaporation (153)
- Stormwater out (154)
- Wastewater out (155)

Cont Bal - Study area.csv

This file contains details of all input and output flows and contaminant loads for the total study area. Flows are reported in kL and masses are reported as raw data values i.e. if input concentrations are specified in mg/L the output loads reported in this file are in mg, or if input concentrations are in cfu/L the outputs loads are in cfu.

Contaminant streams reported in this file are detailed below.

- Imported Water (161)
- Precipitation (160)
- Evaporation (162 + 163 + 164)
- Total SW out (175)
- Total WW out (178)

StudyAreaBalance.csv

The daily study area scale water balance file is called StudyAreaBalance.csv. This file contains information on the water balance components of the whole area that was simulated.

The header lists the items contained the output file, in order. These items are written a new line for each day in the simulation period.

The file consists of 31 items, in the following order:

1.	Year	
2.	Month	
3.	Day	
4.	Precipitation depth	mm/d
5.	Rain depth	mm/d
6.	Snow depth	mm/d
7.	Bulk imported water depth	mm/d
8.	Actual evaporation depth	mm/d
9.	Surface stormwater outflow depth	mm/d
10.	Stormwater baseflow depth	mm/d
11.	Total stormwater outflow depth	mm/d
12.	Wastewater outflow depth	mm/d
13.	Groundwater recharge depth	mm/d
14.	Total irrigation demand depth for land block gardens and open space	mm/d
15.	Total irrigation depth supplied to land block gardens and open space	mm/d
16.	Change in total study area storage depth	mm/d
17.	Water balance depth of study area	mm/d
18.	Precipitation volume	m3/d
19.	Rain volume	m3/d
20.	Snow volume	m3/d
21.	Bulk imported water volume	m3/d
22.	Actual evaporation volume	m3/d
23.	Surface stormwater outflow volume	m3/d
24.	Stormwater baseflow volume	m3/d
25.	Total stormwater outflow volume	m3/d
26.	Wastewater outflow volume	m3/d
27.	Groundwater recharge volume	m3/d
28.	Total irrigation demand volume for land block gardens and open space	m3/d
29.	Total irrigation volume supplied to land block gardens and open space	m3/d
30.	Change in total study area storage volume	m3/d
31.	Water balance volume of study area	m3/d

DailyLandBlock n .csv

The daily land block scale water balance file is called DailyLandBlock n .csv where n is the neighbourhood number. So, there is a separate land block scale water balance output file for each neighbourhood in the catchment. These files contain information on the water balance components of the unit blocks within each neighbourhood.

The header lists the items contained the output file, in order. These items are written a new line for each day in the simulation period.

The file consists of 63 items, in the following order:

1. Year
2. Month
3. Day
4. Precipitation depth mm/d
5. Rain depth mm/d
6. Snowfall depth mm/d
7. Potential evaporation mm/d
8. Garden actual evaporation mm/d
9. Land block actual evaporation mm/d
10. Land block imported water depth mm/d
11. Land block imported water volume $\text{m}^3/\text{hh}/\text{d}$
12. Land block stormwater runoff depth mm/d
13. Land block impervious surface runoff depth (less first flush) mm/d
14. Land block wastewater output depth mm/d
15. Daily change in land block storage depth mm/d
16. Daily land block water balance check mm/d
17. Groundwater recharge depth from garden mm/d
18. Groundwater recharge volume from garden $\text{m}^3/\text{hh}/\text{d}$
19. Groundwater storage level mm
20. Rain day? 1 = yes, 0 = no
21. Garden irrigation demand volume $\text{m}^3/\text{hh}/\text{d}$
22. Garden irrigation demand depth mm/d
23. Garden irrigation volume supplied $\text{m}^3/\text{hh}/\text{d}$

24.	Garden surface runoff depth	mm/d
25.	Volume of paved area runoff spilling onto garden (from non effective paved area)	m ³ /hh/d
26.	Roof runoff depth	mm/d
27.	Roof runoff volume	m ³ /hh/d
28.	Diverted roof runoff first flush volume	m ³ /hh/d
29.	Volume of roof runoff spilling onto garden (from non effective roof area)	m ³ /hh/d
30.	Volume roof runoff spilling land block stormwater output (from non effective roof area)	m ³ /hh/d
31.	Volume of roof runoff draining to garden via spoonrain	m ³ /hh/d
32.	Evaporation from roof	mm/d
33.	Volume of roof runoff entering rainwater tank	m ³ /hh/d
34.	Volume of backup water entering rainwater tank from neighbourhood wastewater store	m ³ /hh/d
35.	Volume of backup water entering rainwater tank from neighbourhood stormwater store	m ³ /hh/d
36.	Demand for water from raintank	m ³ /hh/d
37.	Usage of water from raintank	m ³ /hh/d
38.	Volume of rainwater tank water used in garden	m ³ /hh/d
39.	Volume of rainwater tank water used indoors	m ³ /hh/d
40.	Volume of water spilling from rainwater tank	m ³ /hh/d
41.	Rainwater tank storage level (retained at end of day)	m ³
42.	Rainwater tank not fully meeting demand (event failure)	1 = yes, 0 = no
43.	Deficit in rainwater	m ³ /hh/d
44.	Volume of greywater available for subsurface irrigation	m ³ /hh/d
45.	Demand for subsurface greywater irrigation	m ³ /hh/d
46.	Usage of greywater via subsurface irrigation	m ³ /hh/d
47.	Subsurface greywater not fully meeting demand (event failure)	1 = yes, 0 = no
48.	Deficit in subsurface greywater	m ³ /hh/d
49.	Excess volume of greywater available for subsurface irrigation	m ³ /hh/d
50.	Volume of wastewater entering onsite wastewater unit	m ³ /hh/d
51.	Demand for onsite wastewater	m ³ /hh/d
52.	Usage of onsite wastewater	m ³ /hh/d
53.	Volume of wastewater spilling from onsite wastewater unit	m ³ /hh/d
54.	Volume of wastewater draining to septic disposal leachfield	m ³ /hh/d

55.	Onsite wastewater storage level (retained at end of day)	m^3
56.	Onsite wastewater not fully meeting demand (event failure)	1 = yes, 0 = no
57.	Deficit in onsite wastewater	$\text{m}^3/\text{hh}/\text{d}$
58.	Percentage of onsite wastewater demand met	%
59.	Volume of land block groundwater bore used	$\text{m}^3/\text{hh}/\text{d}$
60.	Land block usage of stormwater from neighbourhood store	$\text{m}^3/\text{hh}/\text{d}$
61.	Land block usage of wastewater from neighbourhood store	$\text{m}^3/\text{hh}/\text{d}$
62.	Land block usage of stormwater from study area store	$\text{m}^3/\text{hh}/\text{d}$
63.	Land block usage of wastewater from study area store	$\text{m}^3/\text{hh}/\text{dYear}$

DailyNeighbourhoodn.csv

The daily cluster scale water balance file is called DailyNeighbourhoodn.csv where n is the neighbourhood number. So, there is a separate neighbourhood scale water balance output file for each cluster in the study area. These files contain information on the water balance components of each neighbourhood.

The header lists the items contained the output file, in order. These items are written a new line for each day in the simulation period.

The file consists of 46 items, in the following order:

64.	Year	
65.	Month	
66.	Day	
67.	Precipitation depth	mm/d
68.	Rain depth	mm/d
69.	Snow depth	mm/d
70.	Neighbourhood imported water depth total (including leakage)	mm/d
71.	Depth of imported water leakage	mm/d
72.	Neighbourhood imported water usage depth	mm/d
73.	neighbourhood actual evaporation depth	mm/d
74.	Depth of stormwater input from upstream neighbourhoods	mm/d
75.	Volume of stormwater input from upstream neighbourhoods	m ³ /d
76.	neighbourhood stormwater surface runoff output depth	mm/d
77.	neighbourhood impervious surface stormwater runoff depth	mm/d
78.	neighbourhood road runoff volume	m ³ /d
79.	neighbourhood stormwater baseflow depth	mm/d
80.	neighbourhood stormwater discharge depth (surface & baseflow)	mm/d
81.	neighbourhood stormwater discharge volume (surface & baseflow)	m ³ /d
82.	Depth of wastewater input from upstream neighbourhoods	mm/d
83.	Volume of wastewater input from upstream neighbourhoods	m ³ /d
84.	Daily neighbourhood wastewater inflow/infiltration volume	m ³ /d
85.	Daily neighbourhood wastewater inflow volume	m ³ /d
86.	Daily neighbourhood wastewater infiltration volume	m ³ /d
87.	neighbourhood wastewater overflow volume	m ³ /d

88.	Daily neighbourhood wastewater exfiltration volume	
89.	neighbourhood wastewater output depth	mm/d
90.	neighbourhood wastewater output volume	m ³ /d
91.	Daily change in neighbourhood storage depth	mm/d
92.	Daily neighbourhood water balance check	mm/d
93.	Garden & POS irrigation demand depth	mm/d
94.	Garden & POS irrigation demand volume	m ³ /d
95.	Garden irrigation demand volume	m ³ /d
96.	Garden & POS irrigation volume supplied	m ³ /d
97.	Daily neighbourhood groundwater recharge depth	mm/d
98.	neighbourhood stormwater store inflow	m ³ /d
99.	neighbourhood stormwater store precipitation input	m ³ /d
100.	neighbourhood stormwater store evaporation	m ³ /d
101.	neighbourhood stormwater store spillage	m ³ /d
102.	neighbourhood stormwater store usage	m ³ /d
103.	neighbourhood stormwater store retained volume	m ³ /d
104.	neighbourhood wastewater store inflow	m ³ /d
105.	neighbourhood wastewater store precipitation input	m ³ /d
106.	neighbourhood wastewater store evaporation	m ³ /d
107.	neighbourhood wastewater store spillage	m ³ /d
108.	neighbourhood wastewater store usage	m ³ /d
109.	neighbourhood wastewater store retained volume	m ³ /d
110.	stormwater used (from any neighbourhood store)	m ³ /d
111.	wastewater used (from any neighbourhood store)	m ³ /d

MthlyNBHn.csv

The monthly neighbourhood scale output file is called MthlyNBHn.csv where *n* is the neighbourhood number. This file contains information on the water balance components of the neighbourhood as well as information on the performance of each water management method.

The header lists the items contained the output file, in order. These items are written a line for each month in the simulation period. The file consists of 69 items, in the following order:

1. Year

2.	Month	
3.	Day	
4.	Precipitation	mm/mth
5.	Potential evaporation	mm/mth
6.	Actual evaporation from pervious area	mm/mth
7.	Actual evaporation from neighbourhood	mm/mth
8.	Depth of actual evapotranspiration from neighbourhoods gardens	mm/mth
9.	Stormwater inflow into neighbourhood	mm/mth
10.	Surface runoff out of neighbourhood	mm/mth
11.	Runoff from pervious surfaces	mm/mth
12.	Impervious surface runoff out of neighbourhood	mm/mth
13.	Base flow	mm/mth
14.	Stormwater discharge out of neighbourhood	mm/mth
15.	Wastewater runoff into neighbourhood	mm/mth
16.	Wastewater runoff out of neighbourhood	mm/mth
17.	Neighbourhood groundwater recharge	mm/mth
18.	Bulk imported water depth into neighbourhood	mm/mth
19.	Bulk imported water volume into neighbourhood	m ³ /mth
20.	Change in neighbourhood total storage	mm/mth
21.	Number of rain days in month	number/mth
22.	Neighbourhood irrigation demand depth	mm/mth
23.	Neighbourhood irrigation demand volume	m ³ /mth
24.	Volume of garden irrigation demand in neighbourhood	m ³ /mth
25.	Volume of irrigation supplied to neighbourhood	m ³ /mth
26.	Volume water for garden irrigation supplied in neighbourhood	m ³ /mth
27.	Total depth of recharge from the neighbourhoods gardens	mm/mth
28.	Volume of water running off roofs into rain tanks	m ³ /mth
29.	Demand for water from rainwater tank	m ³ /mth
30.	Use of rainwater tank water	m ³ /mth
31.	Deficit of rainwater tank water	m ³ /mth
32.	Volume of water spilling from rainwater tanks	m ³ /mth
33.	Number of times rain tanks in neighbourhood failed to fully meet demand	number/mth
34.	Subsurface greywater available for irrigation	m ³ /mth

35. Demand for subsurface greywater irrigation water	m ³ /mth
36. Use of subsurface greywater irrigation water	m ³ /mth
37. Deficit of subsurface greywater irrigation water	m ³ /mth
38. Spillage from subsurface greywater irrigation water	m ³ /mth
39. Number of times subsurface greywater irrigation systems in neighbourhood failed to fully meet demand	number/mth
40. Inflow to on-site wastewater store	m ³ /mth
41. Demand for on-site wastewater	m ³ /mth
42. On-site wastewater store usage	m ³ /mth
43. Spillage from on-site wastewater store	m ³ /mth
44. Deficit of on-site wastewater store	m ³ /mth
45. Monthly volumetric vulnerability of on-site wastewater store	ratio
46. Number of times on-site treated wastewater store in neighbourhood failed to fully meet demand	number/mth
47. Inflow to neighbourhood scale stormwater storage	m ³ /mth
48. Demand for neighbourhood scale stormwater storage	m ³ /mth
49. Use of neighbourhood scale stormwater storage	m ³ /mth
50. Spillage of neighbourhood scale stormwater storage	m ³ /mth
51. Deficit of neighbourhood scale stormwater storage	m ³ /mth
52. Number of times neighbourhood scale stormwater storage failed to fully meet demand	number/mth
53. Inflow to neighbourhood scale wastewater storage	m ³ /mth
54. Demand for neighbourhood scale wastewater store water	m ³ /mth
55. Use of neighbourhood scale wastewater store water	m ³ /mth
56. Spillage of neighbourhood scale wastewater store water	m ³ /mth
57. Deficit of neighbourhood scale wastewater store water	m ³ /mth
58. Number of times neighbourhood scale wastewater store failed to fully meet demand	number/mth
59. Volume available for neighbourhood scale ASR (injection)	m ³ /mth
60. Demand for neighbourhood scale ASR (recovery)	m ³ /mth
61. Amount of water injected into ASR in the neighbourhood	m ³ /mth
62. Amount of water recovered from ASR in the neighbourhood	m ³ /mth
63. Deficit of water available for recovery from ASR	m ³ /mth
64. Number of times ASR in neighbourhood failed to fully meet demand (recovery)	number/mth

65.	Monthly volumetric vulnerability of ASR in neighbourhood	ratio
66.	Net transfer of water into or out of neighbourhood	m ³ /mth
67.	Use of study area scale stormwater storage	m ³ /mth
68.	Use of study area scale wastewater storage	m ³ /mth
69.	Leakage from imported water pipes	mm/mth

MthlyStudyArea.csv

The monthly study area scale output file is called MthlyStudyArea.csv. This file contains information on the water balance components of the study area as well as information on the performance of each water method.

The header lists the items contained the output file, in order. These items are written a line for each month in the simulation period. The file consists of 80 items, in the following order:

1.	Year	
2.	Month	
3.	Days	
4.	Precipitation	mm/mth
5.	Potential evaporation	mm/mth
6.	Study area garden actual evaporation	mm/mth
7.	Study area total pervious area actual evaporation	mm/mth
8.	Study area actual evaporation	mm/mth
9.	Study area stormwater surface runoff output	mm/mth
10.	Study area impervious surface runoff	mm/mth
11.	Study area garden surface runoff	mm/mth
12.	Study area baseflow	mm/mth
13.	Study area stormwater discharge	mm/mth
14.	Study area groundwater recharge	mm/mth
15.	Study area garden groundwater recharge	mm/mth
16.	Study area wastewater output	mm/mth
17.	Study area imported water depth	mm/mth
18.	Study area imported water volume	m ³ /mth
19.	Study area change in storage	mm/mth
20.	Rain days	number/mth

21. Study area irrigation demand volume	m ³ /mth
22. Study area irrigation demand depth	mm/mth
23. Study area irrigation volume supplied	m ³ /mth
24. Study area garden irrigation demand	m ³ /mth
25. Study area garden irrigation supplied	m ³ /mth
26. Study area volume of roof runoff entering rainwater tank	m ³ /mth
27. Study area rainwater tank demand	m ³ /mth
28. Study area rain water tank use	m ³ /mth
29. Study area rainwater tank spillage	m ³ /mth
30. Study area rainwater tank deficit	m ³ /mth
31. Study area rainwater tank event failure (sum of all neighbourhoods)	number/mth
32. Study area subsurface greywater available	m ³ /mth
33. Study area subsurface greywater demand	m ³ /mth
34. Study area subsurface greywater use	m ³ /mth
35. Study area subsurface greywater deficit	m ³ /mth
36. Study area subsurface greywater excess	m ³ /mth
37. Study area subsurface greywater event failure (sum of all neighbourhoods)	number/mth
38. Study area onsite wastewater store inflow	m ³ /mth
39. Study area onsite wastewater store demand	m ³ /mth
40. Study area onsite wastewater store usage	m ³ /mth
41. Study area onsite wastewater store spillage	m ³ /mth
42. Study area onsite wastewater store deficit	m ³ /mth
43. Study area onsite wastewater store vulnerability	m ³ /mth
44. Study area onsite wastewater store event failure	number/mth
45. Total neighbourhood stormwater store inflow in study area	m ³ /mth
46. Total neighbourhood stormwater store demand in study area	m ³ /mth
47. Total neighbourhood stormwater store usage in study area	m ³ /mth
48. Total neighbourhood stormwater store deficit in study area	m ³ /mth
49. Total neighbourhood stormwater store spillage in study area	m ³ /mth
50. Total neighbourhood stormwater store event failure in study area	number/mth
51. Neighbourhood wastewater store inflow in study area	m ³ /mth
52. Neighbourhood wastewater store demand in study area	m ³ /mth
53. Neighbourhood wastewater store usage in study area	m ³ /mth

54.	Neighbourhood wastewater store spillage in study area	m ³ /mth
55.	Neighbourhood wastewater store deficit in study area	m ³ /mth
56.	Neighbourhood wastewater store event failure in study area	number/mth
57.	Study area ASR volume available for injection	m ³ /mth
58.	Study area ASR demand for recovery	m ³ /mth
59.	Study area ASR volume injected	m ³ /mth
60.	Study area ASR volume recovered	m ³ /mth
61.	Study area ASR deficit	m ³ /mth
62.	Study area ASR event failure	m ³ /mth
63.	Study area ASR volumetric vulnerability	m ³ /mth
64.	Study area scale stormwater store inflow	m ³ /mth
65.	Study area scale stormwater store demand	m ³ /mth
66.	Study area scale stormwater store usage	m ³ /mth
67.	Study area scale stormwater store spillage	m ³ /mth
68.	Study area scale stormwater store deficit	m ³ /mth
69.	Study area scale stormwater store event failure	number/mth
70.	Study area scale stormwater store volumetric vulnerability	ratio
71.	Study area scale wastewater store inflow	m ³ /mth
72.	Study area scale wastewater store demand	m ³ /mth
73.	Study area scale wastewater store usage	m ³ /mth
74.	Study area scale wastewater store spillage	m ³ /mth
75.	Study area scale wastewater store deficit	m ³ /mth
76.	Study area scale wastewater store spillage	number/mth
77.	Study area scale wastewater store volumetric vulnerability	ratio
78.	Neighbourhood stormwater store supply to land blocks in study area	m ³ /mth
79.	Neighbourhood wastewater store supply to land blocks in study area	m ³ /mth
80.	Study area stormwater store supply to land blocks	m ³ /mth

YearNBHn.csv

The annual neighbourhood scale output file is called YearlyNBHn.csv where *n* is the neighbourhood number. This file contains information on the water balance components of the neighbourhood as well as information on the performance of each water management method.

The header lists the items contained the output file, in order. These items are written a line for each year in the simulation period. The file consists of 66 items, in the following order:

1.	Year	
2.	Precipitation	mm/y
3.	Potential evaporation	mm/y
4.	Neighbourhood actual evaporation	mm/y
5.	Neighbourhood pervious area actual evaporation	mm/y
6.	Depth of actual evapotranspiration from neighbourhoods gardens	mm/y
7.	Neighbourhood stormwater input (from upstream neighbourhoods)	mm/y
8.	Neighbourhood stormwater surface runoff output	mm/y
9.	Neighbourhood impervious surface runoff	mm/y
10.	Runoff from gardens in neighbourhood	mm/y
11.	Neighbourhood baseflow	mm/y
12.	Neighbourhood stormwater discharge	mm/y
13.	Neighbourhood wastewater input	mm/y
14.	Neighbourhood wastewater output	mm/y
15.	Depth of groundwater recharge from neighbourhood	mm/y
16.	Depth of groundwater recharge from neighbourhoods gardens	mm/y
17.	Neighbourhood imported water depth	mm/y
18.	Neighbourhood imported water volume	m ³ /y
19.	Neighbourhood change in total storage	mm/y
20.	Rain days	number/y
21.	Neighbourhood irrigation demand volume	m ³ /y
22.	Neighbourhood irrigation demand depth	mm/y
23.	Neighbourhood garden irrigation demand volume	m ³ /y
24.	Volume of irrigation supplied to neighbourhood	m ³ /y
25.	Volume water for garden irrigation supplied in neighbourhood	m ³ /y
26.	Neighbourhood irrigated area	m ²
27.	Volume of water running off roofs into rain tanks	m ³ /y
28.	Demand for water from rainwater tank	m ³ /y
29.	Use of rainwater tank water	m ³ /y
30.	Volume of water spilling from rainwater tanks	m ³ /y

31. Deficit of rainwater tank water	m ³ /y
32. Number of times rain tanks in neighbourhood failed to fully meet demand	number/y
33. Subsurface greywater available for irrigation	m ³ /y
34. Demand for subsurface greywater irrigation water	m ³ /y
35. Use of subsurface greywater irrigation water	m ³ /y
36. Spillage from subsurface greywater irrigation water	m ³ /y
37. Deficit of subsurface greywater irrigation water	m ³ /y
38. Number of times subsurface greywater irrigation systems in neighbourhood failed to fully meet demand	number/y
39. Inflow to on-site wastewater store	m ³ /y
40. Demand for on-site wastewater	m ³ /y
41. On-site wastewater store usage	m ³ /y
42. Spillage from on-site wastewater store	m ³ /y
43. Deficit of on-site wastewater store	m ³ /y
44. Annual volumetric vulnerability of on-site wastewater store	ratio
45. Number of times on-site treated wastewater store in neighbourhood failed to fully meet demand	number/y
46. Inflow to neighbourhood stormwater store	m ³ /y
47. Neighbourhood stormwater store demand	m ³ /y
48. Neighbourhood stormwater store usage	m ³ /y
49. Neighbourhood stormwater store deficit	m ³ /y
50. Neighbourhood stormwater store spillage	m ³ /y
51. Neighbourhood stormwater store event failure	number/y
52. Inflow to neighbourhood scale wastewater storage	m ³ /y
53. Demand for neighbourhood scale wastewater store water	m ³ /y
54. Use of neighbourhood scale wastewater store water	m ³ /y
55. Spillage of neighbourhood scale wastewater store water	m ³ /y
56. Deficit of neighbourhood scale wastewater store water	m ³ /y
57. Number of times neighbourhood scale wastewater store failed to fully meet demand	number/y
58. Volume available for neighbourhood scale ASR (injection)	m ³ /y
59. Demand for neighbourhood scale ASR (recovery)	m ³ /y
60. Amount of water injected into ASR in the neighbourhood	m ³ /y
61. Amount of water recovered form ASR in the neighbourhood	m ³ /y

62.	Deficit of water available for recovery from ASR	m ³ /y
63.	Number of times ASR in neighbourhood failed to fully meet demand (recovery)	number/y
64.	Annual volumetric vulnerability of ASR in neighbourhood	ratio
65.	Net transfer of water into or out of neighbourhood	m ³ /y
66.	Leakage from imported water pipes	mm/y

YearStudyArea.csv

The annual study area scale output file is called YearlyStudyArea.csv. This file contains information on the water balance components of the study area as well as information on the performance of each water management method.

The header lists the items contained the output file, in order. These items are written a line for each year in the simulation period. The file consists of 76 items, in the following order:

1.	Year	
2.	Precipitation	mm/y
3.	Potential evaporation	mm/y
4.	Study area total pervious area actual evaporation	mm/y
5.	Study area actual evaporation	mm/y
6.	Study area garden actual evaporation	mm/y
7.	Study area stormwater surface runoff output	mm/y
8.	Study area garden surface runoff	mm/y
9.	Study area impervious surface runoff	mm/y
10.	Study area baseflow	mm/y
11.	Study area stormwater discharge	mm/y
12.	Study area groundwater recharge	mm/y
13.	Study area garden groundwater recharge	mm/y
14.	Study area wastewater output	mm/y
15.	Study area imported water depth	mm/y
16.	Study area imported water volume	m ³ /y
17.	Study area change in storage	mm/y
18.	Rain days	number
19.	Study area irrigation demand volume	m ³ /y

20.	Study area irrigation demand depth	mm/y
21.	Study area garden irrigation demand	m ³ /y
22.	Total irrigation area	m ²
23.	Study area irrigation volume supplied	m ³ /y
24.	Study area garden irrigation supplied	m ³ /y
25.	Study area volume of roof runoff entering rainwater tank	m ³ /y
26.	Study area rainwater tank demand	m ³ /y
27.	Study area rain water tank use	m ³ /y
28.	Study area rainwater tank spillage	m ³ /y
29.	Study area rainwater tank deficit	m ³ /y
30.	Study area rainwater tank event failure (sum of all neighbourhoods)	number/y
31.	Study area subsurface greywater available	m ³ /y
32.	Study area subsurface greywater demand	m ³ /y
33.	Study area subsurface greywater use	m ³ /y
34.	Study area subsurface greywater excess	m ³ /y
35.	Study area subsurface greywater deficit	m ³ /y
36.	Study area subsurface greywater event failure (sum of all neighbourhoods)	number/y
37.	Study area onsite wastewater store inflow	m ³ /y
38.	Study area onsite wastewater store demand	m ³ /y
39.	Study area onsite wastewater store usage	m ³ /y
40.	Study area onsite wastewater store spillage	m ³ /y
41.	Study area onsite wastewater store deficit	m ³ /y
42.	Study area onsite wastewater store vulnerability	ratio
43.	Study area onsite wastewater store event failure	number/y
44.	Total neighbourhood stormwater store inflow in study area	m ³ /y
45.	Total neighbourhood stormwater store demand in study area	m ³ /y
46.	Total neighbourhood stormwater store usage in study area	m ³ /y
47.	Total neighbourhood stormwater store spillage in study area	m ³ /y
48.	Total neighbourhood stormwater store deficit in study area	m ³ /y
49.	Total neighbourhood stormwater store event failure in study area	number/y
50.	Total neighbourhood wastewater store inflow in study area	m ³ /y
51.	Total neighbourhood wastewater store demand in study area	m ³ /y
52.	Total neighbourhood wastewater store usage in study area	m ³ /y

53. Total neighbourhood wastewater store spillage in study area	m ³ /y
54. Total neighbourhood wastewater store deficit in study area	m ³ /y
55. Total neighbourhood wastewater store event failure in study area	number/y
56. Study area ASR volume available for injection	m ³ /y
57. Study area ASR demand for recovery	m ³ /y
58. Study area ASR volume injected	m ³ /y
59. Study area ASR volume recovered	m ³ /y
60. Study area ASR deficit	m ³ /y
61. Study area ASR event failure	number/y
62. Study area ASR volumetric vulnerability	ratio
63. Study area scale stormwater store inflow	m ³ /y
64. Study area scale stormwater store demand	m ³ /y
65. Study area scale stormwater store usage	m ³ /y
66. Study area scale stormwater store spillage	m ³ /y
67. Study area scale stormwater store deficit	m ³ /y
68. Study area scale stormwater store event failure	number/y
69. Study area scale stormwater store volumetric vulnerability	ratio
70. Study area scale wastewater store inflow	m ³ /y
71. Study area scale wastewater store demand	m ³ /y
72. Study area scale wastewater store usage	m ³ /y
73. Study area scale wastewater store spillage	m ³ /y
74. Study area scale wastewater store deficit	m ³ /y
75. Study area scale wastewater store event failure	number/y
76. Study area scale wastewater store volumetric vulnerability ratio	

AISUWRS output files

UFMGardenToGW.txt

UFMPOSToGW.txt

UFMSWInfiltrationBasinToGW.txt

UFMTapToGW.txt

These files provide the AISUWRS unsaturated flow models and groundwater models with Garden, Public Open Space, Stormwater Infiltration from an Infiltration Basin and leakage from the potable pipe network, flows and contaminant loads

[PlmUVQSWinput.txt](#)

[PlmUVQWWinput.txt](#)

These files provide the AISUWRS pipe leakage model input flows and contaminant loads

Worksheets

This section contains the worksheets you will use during the tutorial. Each screen within UVQ has a corresponding worksheet. You will add information to these worksheets throughout the tutorial, then use the information to create your simulations. The worksheets you will use are:

- Project information
- Physical characteristics of land blocks and neighbourhoods
- Water Flow
- Calibrated variables
- Land Block Parameters
- Neighbourhood Parameters
- Study Area Parameters

Project Information	
Field	Data
Project description	
Study area (ha)	
Number of neighbourhoods	
Soil store types	
Contaminants for analysis in this study	
Optional user defined contaminants	

Physical Characteristics of Land Blocks and Neighbourhoods

Physical Characteristics of Land Blocks and Neighbourhoods			
Field	Neighbourhood 1	Neighbourhood 2	Neighbourhood 3
Neighbourhood Frame			
Total Area (ha)			
Road Area (ha)			
Open Space Area (ha)			
Percentage of Open Space Irrigated (%)			
Imported supply leakage (%)			
Wastewater as Exfiltration (ratio)			
Land Block Frame			
Number of Land Blocks			
Block Area (m ²)			
Average Occupancy			
Garden Area (m ²)			
Roof Area (m ²)			
Paved Area (m ²)			
Percentage of Garden Irrigated (%)			
Proportion Roof Runoff to Spoondrain (ratio)			
Indoor Water Usage & Contaminants Frame			
Kitchen L/c/d			
Bathroom L/c/d			
Toilet L/c/d			
Laundry L/c/d			
Bathroom Contaminant Loads (mg/c/d)			
Toilet Contaminant Loads (mg/c/d)			
Kitchen Contaminant Loads (mg/c/d)			

Physical Characteristics of Land Blocks and Neighbourhoods			
Field	Neighbourhood 1	Neighbourhood 2	Neighbourhood 3
Laundry Contaminant Loads (mg/c/d)			
Other Contaminants Frame			
Road Runoff (mg/L)			
Roof First Flush (mg/L)			
Fertiliser to POS (mg total)			
Evaporation (mg/L)			
Ground Water (mg/L)			
Imported (mg/L)			
Rainfall (mg/L)			
Pavement Runoff (mg/L)			
Roof Runoff (mg/L)			

Water Flow

Stormwater and Wastewater Flow Paths of Neighbourhoods			
Field	Neighbourhood 1	Neighbourhood 2	Neighbourhood 3
Stormwater from Neighbourhood goes to:			
Wastewater from Neighbourhood goes to:			

Calibration Variables

Calibration Variables ~first cut estimates pre-calibration			
Field	Neighbourhood 1	Neighbourhood 2	Neighbourhood 3
Stormwater Frame			
Percentage Area of Soil Store 1			
Capacity of Soil Store 1 (mm)			
Capacity of Soil Store 2 (mm)			
Roof Area Maximum Initial Loss (mm)			
Effective Roof Area (%)			
Paved Area Maximum Initial Loss (mm)			
Effective Paved Area (%)			
Road Area Maximum Initial Loss (mm)			
Effective Road Area (%)			
Base Flow Index (ratio)			
Base Flow Recession Constant (ratio)			
Contaminant Soil Store Removal Frame			
Contaminants			
Wastewater Frame			
Infiltration Index (ratio)			
Infiltration store recession constant (ratio)			
Percentage Surface Runoff as Inflow			
Dry Weather Overflow Rate (%)			
Wastewater System Capacity (kL)			
Irrigation Frame			
Garden Trigger to Irrigate (ratio)			
Open Space Trigger to Irrigate (ratio)			

Observed Neighbourhood Flow Volumes and Quality for Calibration			
Field	Neighbourhood 1	Neighbourhood 2	Neighbourhood 3
Average Volumes Frame – Neighbourhood Tab			
Imported Water – Observed (kL/y or ML/y)			
Wastewater – Observed (kL/y or ML/y)			
Stormwater – Observed (kL/y or ML/y)			
Quality Frame (contaminants) – Neighbourhood Tab			
Stormwater – Observed			
Wastewater – Observed			

Observed Study Area Flow Volumes and Quality for Calibration			
Field	Study Area		
Average Volumes Frame – Study Area Tab			
Imported Water – Observed (kL/y or ML/y)			
Wastewater – Observed (kL/y or ML/y)			
Stormwater – Observed (kL/y or ML/y)			
Quality Frame (contaminants) – Study Area Tab			
Stormwater - Observed			
Wastewater – Observed			

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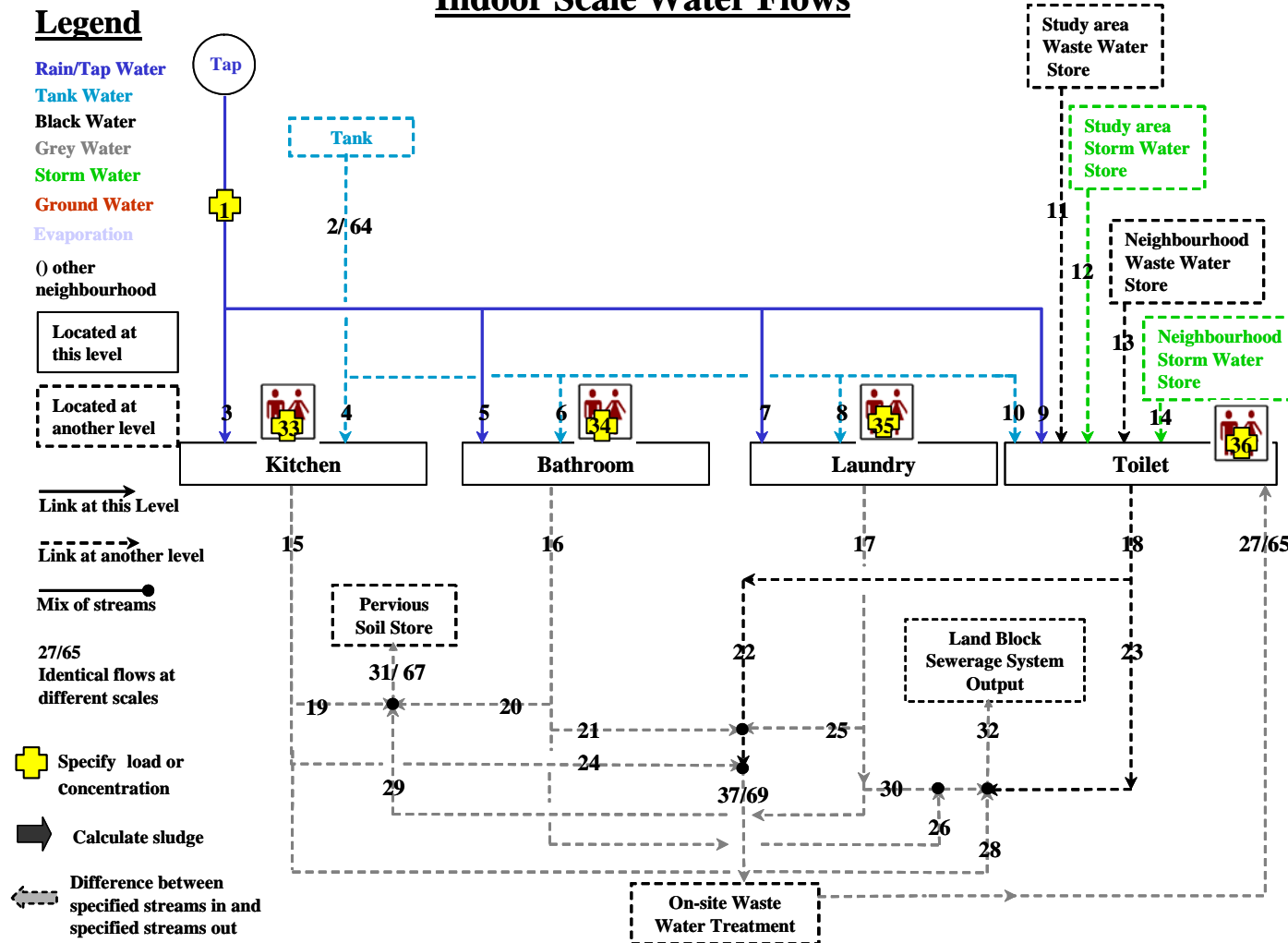
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Appendix I: Contaminant Flow Diagrams

Indoor Scale Water Flows



Legend

Rain/Tap Water

Tank Water

Black Water

Grey Water

Storm Water

Ground Water

Evaporation

() other
neighbourhood

Located at
this level

Located at
another level

Link at this Level

Link at another level

Mix of streams

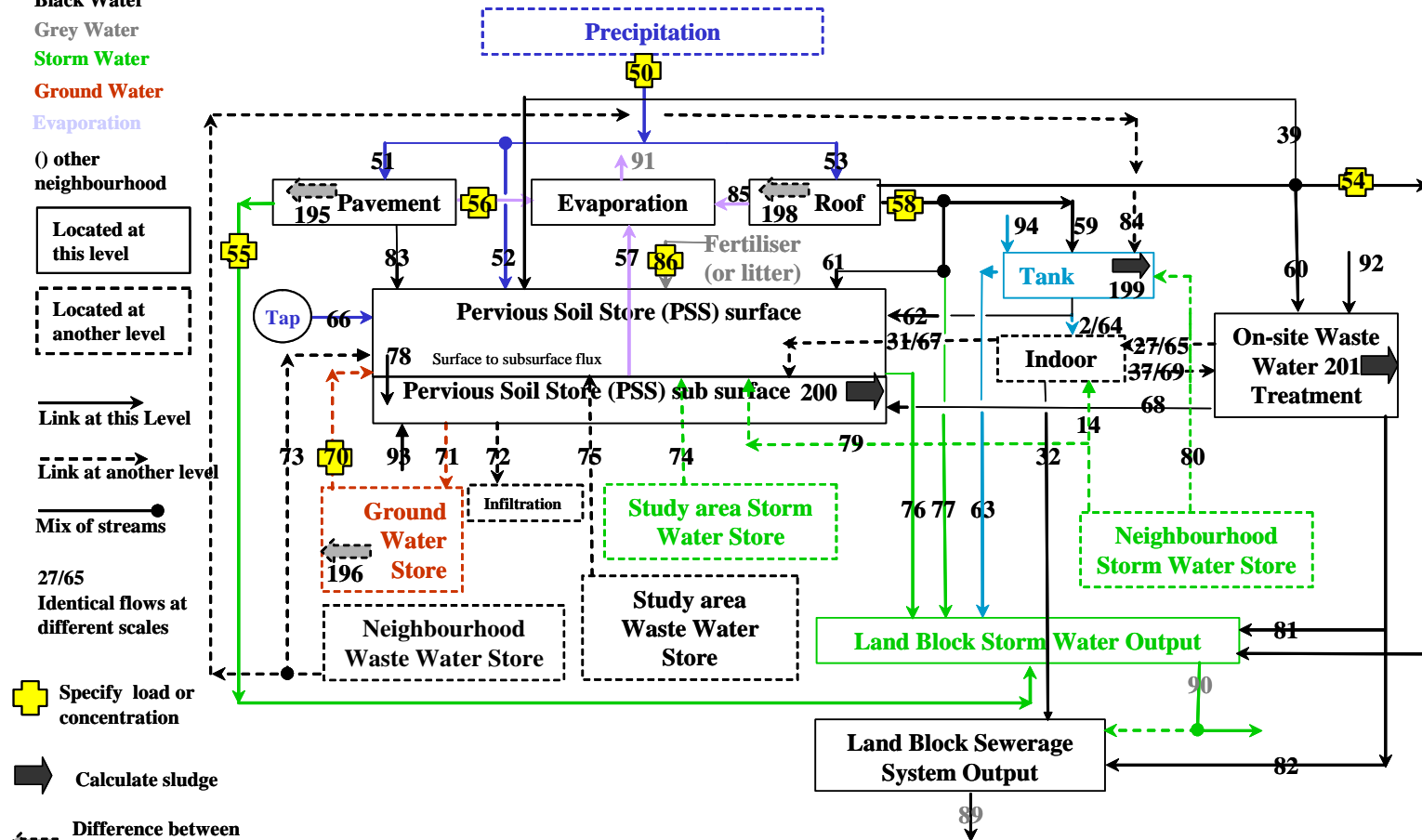
27/65
Identical flows at
different scales

Specify load or
concentration

Calculate sludge

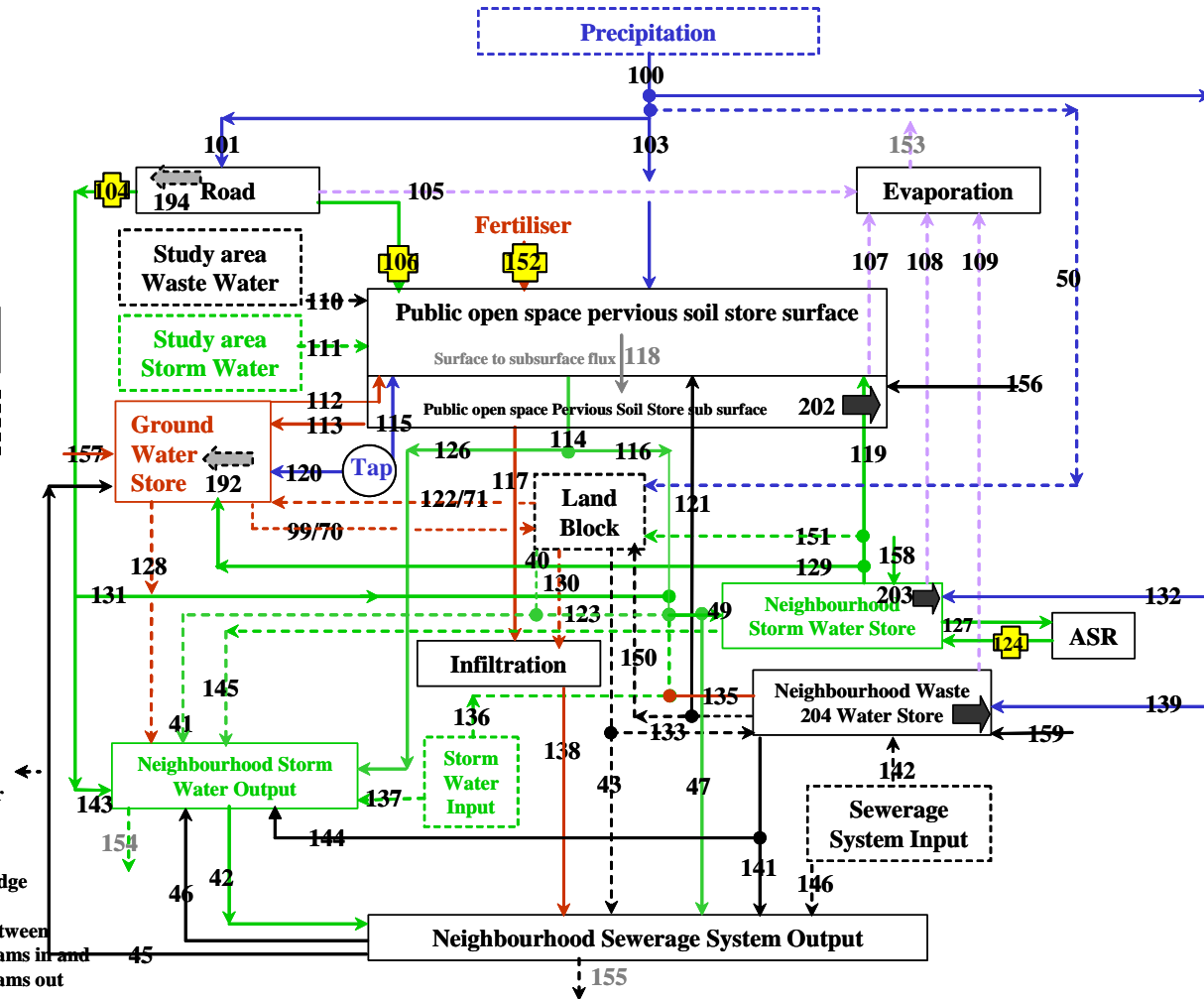
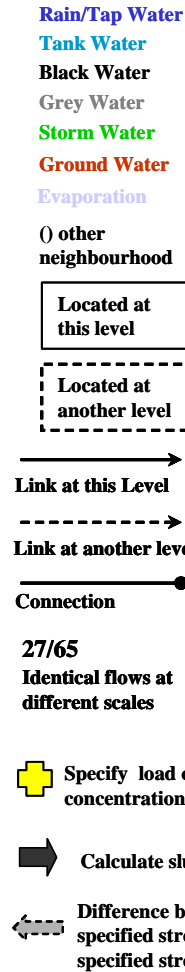
Difference between
specified streams in and
specified streams out

Land Block Scale Contaminant Flows



Neighbourhood Contaminant Flows

Legend



Study area Water Flows

Legend

Rain/Tap Water

Tank Water

Black Water

Grey Water

Storm Water

Ground Water

Evaporation

() other
neighbourhood

Located at
this level

Located at
another level

→
Link at this Level

- - - - -
Link at another level

27/65
Identical flows at
different scales

⊕ Specify load or
concentration

➡ Calculate sludge

⬅ Difference between
specified streams in and
specified streams out

